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Control of Industrial VOC (Volatile Organic Compound) Emissions by Catalytic Incineration Volume 2. Final Report on Catalytic Incinerator Performance at Six Industrial Sites

Radian Corp., Durham, NC

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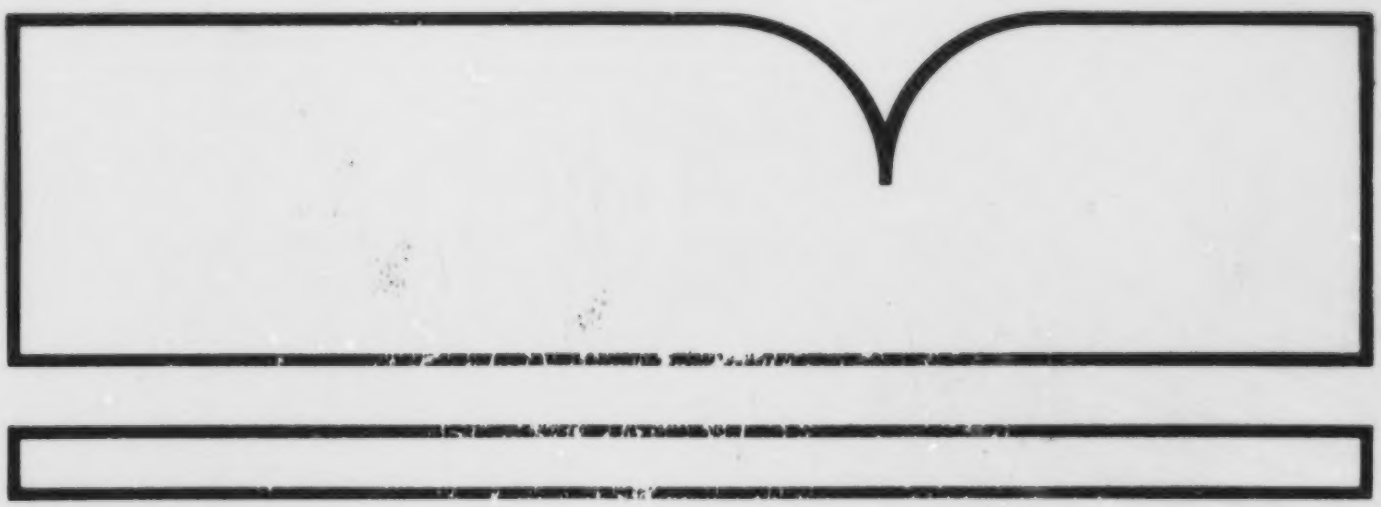

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CONTROL OF INDUSTRIAL VOC EMISSIONS BY CATALYTIC INCINERATION
Volume 2. Final Report on Catalytic Incinerator Performance at Six Industrial Sites

by

M. A. Palazzolo
R. M. Parks
K. K. Fidler
Radian Corporation
Progress Center
3200 E. Chapel Hill Rd./Nelson Hwy.
Research Triangle Park, North Carolina 27709

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EPA Project Officer: P. Jeff Chappell
Industrial Environmental Research Laboratory
Office of Environmental Engineering and Technology
Research Triangle Park, North Carolina 27711

INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

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16. ABSTRACT The report is part of a two-phase EPA effort to assess the performance, suitability, and costs of various technologies to control emissions of volatile organic compounds (VOCs). In Phase 1, information was assembled from the literature on the use and cost of using catalytic incineration for VOC control. Results included: (1) a review of current and developing catalytic incineration technology, (2) an assessment of the overall performance of catalytic incinerators, (3) a review of applications where catalytic incinerators are used, (4) a comparative analysis of catalytic incineration with other competing VOC controls, (5) an examination of available methods for emission testing catalytic incinerators, and (6) an assessment of the need for additional performance test data. Phase 2 was a test program designed to increase the catalytic incinerator performance data base. It resulted in reports documenting the performance of eight catalytic incinerators at six industrial sites. The incinerators were used to control VOC emissions from solvent evaporation processes at can coating, coil coating, magnet wire, and graphic arts printing plants. Performance was measured at several process conditions at each site. Incinerator performance was characterized in terms of destruction efficiency, outlet solvent concentration, and energy usage. Design and operating data were collected.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Magnet Wire	Pollution Control	13B	11F, 20C
Incinerators	Graphic Arts	Stationary Sources		14E
Catalysis	Printing Equipment	Catalytic Incineration	07D	
Organic Compounds		Volatile Organic Compounds	07C	
Volatility			20M	
Solvents		Solvent Evaporation	11K	
Evaporation		Can Coating		

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ABSTRACT

The emission of volatile organic compounds (VOCs) from industrial plants significantly increases ambient levels of photochemical oxidants, ozone, and smog. Control of industrial VOC emissions, therefore, can result in substantial environmental benefits. This study was part of a comprehensive effort by EPA/IERL-RTP to assess the performance, suitability and costs of various VOC control technologies. The objectives of the EPA program were two-fold:

(1) to provide an overview of how catalytic incineration is applied to control industrial VOC emissions and to assess the overall performance, applicability, and costs as compared to alternate VOC control technologies, and

(2) to gather actual performance data through a field testing program on existing operating industrial catalytic incinerators.

The task of meeting these objectives was accomplished in two phases. In the first phase, information was assembled from the literature on the use and cost of using catalytic incineration for VOC control. This phase of the study provides results in the following areas:

- A review of current and developing catalytic incineration technology,
- an assessment of the overall performance of catalytic incinerators,
- a review of applications where catalytic incinerators are used,
- a comparative analysis of catalytic incineration with other competing VOC controls,
- an examination of the available methods for emission testing catalytic incinerators, and
- an assessment of the need for additional performance test data.

The second phase was a testing program designed to increase the catalytic incinerator performance data base. The testing program was planned so that 8 catalytic incinerators at industrial sites would be tested.

The outputs from this phase of the program consisted of a series of reports documenting the performance of 8 catalytic incinerators at 6 industrial sites. All 8 incinerators were used to control VOC emissions from solvent evaporation processes. Incinerators at can coating, coil coating, magnet wire, and graphic arts printing plants were tested. The performance measurements were made at several process conditions at each of the sites visited. Incinerator performance was characterized in terms of destruction efficiency, outlet solvent concentration, and energy usage. Incinerator design and operating data, such as operating temperature, solvent type, catalyst volume and age, were collected to document the operating conditions during the tests.

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SECTION 1

INTRODUCTION

Radian Corporation has conducted for the U.S. Environmental Protection Agency a testing program (Contract No. 68-02-3171, Work Assignment 50) to document the performance of catalytic incinerators applied to industrial processes for volatile organic compound (VOC) control. This final report summarizes the results of the testing program and presents a comparative analysis of results for all the incinerators tested.

VOC emissions are of concern to EPA because they may react photochemically in the atmosphere to form photochemical oxidants. National Ambient Air Quality Standards (NAAQS) for photochemical oxidants are routinely exceeded in many areas of the United States. The objectives of the EPA program under which this work was done are two-fold:

(1) to provide an overview of how catalytic incineration is applied to control industrial VOC emissions and to access the overall performance typically achieved in various applications, and

(2) to gather actual performance data through an EPA sponsored testing program on operating industrial catalytic incinerators.

The first objective was addressed in an earlier study done by Radian Corporation and the results are contained in Volume 1 of this report, entitled "Assessment of Catalytic Incineration and Competing Controls." The second objective was accomplished in the current testing program. The results of the testing program are contained in this Volume 2 final report and a series of six site-specific test reports (Volumes 3-8). The

site-specific reports are hereafter referred to in this final report as "Site Test Reports." These test reports contain detailed information on the incinerator tests at each of the industrial sites.

The approach taken to gather test data on industrial catalytic incinerators consisted of (1) developing plant-specific test plans and test methods to characterize incinerator performance and (2) performing several days of comprehensive on-site testing on each incinerator. The testing focused on simultaneous monitoring of inlet and outlet VOC concentrations and measurement of incinerator operating conditions. This testing resulted in a data base on catalytic incineration that:

- is well documented in terms of incinerator and process parameters,
- uses the same testing methods on a number of catalytic incinerators applied in several industries, and
- provides continuous incinerator performance data over several days and numerous conditions.

The data contained in this report accurately represent the performance of the incinerators tested. It should be noted that other incinerators applied to similar processes may achieve better or poorer performance, depending on site-specific factors such as incinerator design and operation. The effect of major design and operating parameters on performance are discussed in this and other volumes of this report.

Section 2.0 of this report contains a summary of the findings of the test program while Section 3.0 discusses the criteria used to select the plant sites that were tested. Section 4.0 contains process descriptions of all the plants tested. Test procedures used during the course of the program are discussed in Section 5.0 and the test results are discussed in Section 6.0. Recommendations from the test effort are included in Section 7.0.

SECTION 2

SUMMARY

A total of eight catalytic incinerators were tested at six industrial sites between November 1982 and March 1983. Selection of the test sites was based on several criteria including process type and incinerator design characteristics.

All eight incinerators were used to control volatile organic compound (VOC) emissions from solvent evaporation processes. In these processes, pigments, inks or resins dissolved in organic solvents are applied to metal or paper surfaces. The solvents are then driven off the surfaces in drying ovens and the oven exhaust is ducted to a catalytic incinerator for solvent destruction. Incinerators at can coating, coil coating, magnet wire and graphic arts printing plants were tested.

Incinerator performance was characterized in terms of destruction efficiency, outlet solvent concentration and energy usage. Inlet and outlet solvent concentrations were monitored with hydrocarbon analyzers during a nominal 1-week test period at each site. Incinerator design and operating data, such as operating temperature, solvent type, catalyst volume and catalyst age, were collected on each incinerator to document the operating conditions during the test.

Four of the eight incinerators showed destruction efficiencies in excess of 90 percent under typical plant and incinerator operating conditions. These incinerators were applied in the can coating, coil coating, and graphic arts printing industries. Destruction efficiencies for each incinerator generally varied over a narrow range for different coatings or inks.

A fifth incinerator showed slightly lower efficiencies between 88 and 94 percent. This incinerator was also applied in the can coating industry.

The three remaining incinerators all showed comparatively low destruction efficiencies of approximately 80 percent. The lower efficiencies at two of these sites is attributed to the catalyst condition. One of the catalyst beds was fouled or deactivated by high temperature operation or material masking and the other catalyst bed appears to have been deactivated by normal catalyst aging. The lower efficiency at the third site is due to a lower solvent laden air (SLA) residence time. This incinerator, which was a much older design, had a SLA residence time approximately half that of the newer incinerators tested.

Two of the three incinerators that showed comparatively low destruction efficiencies were applied in the graphic arts printing industry and the third incinerator was applied to a magnet wire coating line.

Outlet total hydrocarbon (THC) concentrations based on EPA Method 25A ranged widely for the eight incinerators from 46 to 1600 parts per million by volume carbon (ppmv). However, measured outlet concentrations were below 350 ppmv for six of the eight incinerators.

Energy usage for most of the incinerators ranged from 78 to 270 kJ/Nm^3 (2.1 to 7.2 Btu/scf) of waste gas treated. One incinerator had an estimated energy usage of 780 kJ/Nm^3 (21 Btu/scf).

Comparison of destruction efficiencies measured according to Method 25A and Method 18 showed good agreement.

At several test sites, the incinerator operating temperature was varied to observe the effect of temperature on performance. As expected, destruction efficiency increased with increasing operating temperature.

However, the effect of temperature on destruction efficiency varied widely for the different incinerators. Of five incinerators for which the temperature was varied, two showed a fairly small effect of temperature and three showed a comparatively large effect. The largest increase in efficiency for a temperature rise of 14°C (25°F) was 2.5 percent, from 84.0 to 86.5.

Inlet concentration as measured by Method 25A was also observed to have an effect on destruction efficiency. For similar catalyst bed inlet temperatures, destruction efficiency increased with increasing inlet concentration. Variations in inlet concentration generally occurred for different coatings and coating rates. The effect of inlet concentration was found to be greatest for incinerators operating at efficiencies below 85 percent.

SECTION 3

TEST SITE SELECTION CRITERIA

The criteria used to select host sites for the catalytic incineration test program are discussed in this section. These criteria were based on the data gaps and information needs identified in Volume I of this report, entitled "Control of Industrial VOC Emissions by Catalytic Incineration." All of the objectives of the EPA catalytic incineration program, which were discussed in Section 1.0, were considered and evaluated as the host sites were selected and tested.

The catalytic incinerator testing program was designed to examine catalytic incinerator performance from two perspectives: (1) how well the technology performed when applied to specific industries that typically used catalytic incineration and (2) how incinerator performance was related to a variety of process variables.

As reported in Volume 1, part of the catalytic incineration program involved identifying industrial sites that used catalytic incineration for VOC control. A summary of the sites identified is given in Table 3-1 by generic industry type. It is important to note that this list of plants is a random compilation of sites based on available data. As such, the relative number of plants identified in any industrial sector may be biased due to the availability of information in that particular sector.

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TABLE 3-1. SUMMARY OF SITES IDENTIFIED

Industry	Number of Sites Identified
Metal can coating	25
Magnet wire enameling	24
Organic chemical manufacturing	20
Printing operations	17
Paper coating	5
Asphalt blowing	5
Alkyd varnish production	4
Tire manufacturing	4
Foundry core production	3
Fabric coating	3
Metal coil coating	3
Other metal coating operations	6
Other non-metal coating operations	8
Miscellaneous	21
TOTAL	149

The 149 sites listed in Table 3-1 formed the basis for the site selection task. In order to fairly access the performance of catalytic incinerators in representative industries, an attempt was made to contact sites that would provide an adequate cross-section of the major industries using catalytic incineration. Of the 149 sites identified in Table 3-1, 86 sites, or 58 percent are represented by four industries: metal can coating, magnetic wire production, organic chemical manufacturing and printing operations.

In an effort to test at least one incinerator in each of these four major industries, 8 to 10 plants were contacted in each category. Industry participation in the test program was strictly voluntary and several factors resulted in more plants being tested in some areas and none in others. Table 3-2 lists the final industry make-up of the plants included in the test program.

TABLE 3-2. SOURCE CATEGORIES TESTED

Industry	Number of Incinerators Tested	Number of Plants Represented
Metal Can Coating	3	2
Printing Operations	3	2
Magnetic Wire Enameling	1	1
Metal Coil Coating	1	1
Total	8	6

An organic chemical site was not selected and tested because the plants contacted were unwilling to have their units tested in the particular time frame of the testing program. This was due in part to the current depressed economic situation. Many plants were running at levels considerably below their standard operating ranges and some plants had actually ceased operations. In these cases, the plants made the decision not to test due to potential non-representative operation of the process and incinerators.

In some other industries the plants that were contacted indicated that production levels were so high that any disruption of plant operation could not be tolerated. In these cases, the plants were likewise not tested.

Another important consideration in selecting test sites was geographic density. An attempt was made to choose sites in areas where other potential sites existed so that travel costs could be reduced. This attempt was not as successful as desired and was not held as a constraint on the site selection process.

In addition to testing a variety of industries, the testing program also evaluated incinerator performance as it relates to process variables.

There are many process variables affecting performance, and they can be organized into two categories: waste gas characteristics and catalytic incinerator operating parameters. These are presented in Table 3-3.

TABLE 3-3. FACTORS AFFECTING CATALYTIC INCINERATION PERFORMANCE

Waste Gas Characteristics
VOC concentration
temperature
flowrate
VOC species
Catalytic Incinerator Parameters
catalyst volume, age, and type
heat recovery configuration
operating temperature
age of incinerator
annual operating hours and consistency of operation
incinerator design
catalyst bed residence time

In organizing the test program, as many of these parameters as possible were considered. The extent to which the data base represents the possible range of operating variables in each industry category was limited by the number of sites tested. Nevertheless, test sites were successfully selected to provide a data base spanning a wide range of waste gas characteristics and incinerator operating conditions. These characteristics and conditions are presented and discussed in Section 6.1. Additional discussion of incinerator operating conditions at each site is contained in the Site Test Reports.

SECTION 4

PROCESS DESCRIPTIONS

Plants C-1 through C-6 represent a variety of industrial processes which utilize catalytic incinerators to destroy VOC emissions. Process descriptions for Plants C-1 through C-6 are presented in the following subsections. Included in each process description is a brief description of the incinerators tested at each plant and typical operating parameters for the tested incinerators. More complete discussions of the various processes and incinerator operating parameters are included in the Site Test Reports for Plants C-1 through C-6.

4.1 PLANT C-1

Plant C-1 produces decorated metal sheets and falls under SIC 3411, the metal can industry. In this process, pigments or varnishes dissolved in solvents are applied to metal sheets in thin coats. The solvents are then driven off the metal sheets in drying ovens and the oven exhaust is ducted to a catalytic incinerator for solvent destruction.

Two incinerators, incinerators 27 and 28, were tested at Plant C-1. Each incinerator is used to destroy solvent emissions from a single sheet metal coating line. Fugitive VOC emissions from a roll-type coating applicator are captured with a hood and ducted to the incinerator with the exhaust from three oven zones.

Coatings used at Plant C-1 are purchased pre-mixed from coating manufactures. Major solvents identified in the coatings include methylisobutyl ketone (MIBK), toluene, xylenes and ethyl benzenes.

A schematic diagram of the relationship between each oven and incinerator at Plant C-1 is shown in Figure 4-1. Both incinerators tested have identical configurations.

As shown in Figure 4-1, solvent laden air (SLA) drawn from the oven by a large blower passes into the burner zone of the incinerator. The SLA is heated by the combustion of natural gas and then passes through the catalyst bed where solvents in the SLA are oxidized. Approximately 40 percent of the incinerator outlet gas, typically at 400°C (750°F), is recirculated to the three oven zones. Dampers control the amount of air recirculated to maintain a preset oven zone temperature. This zone temperature varies with the coating being dried. The rest of the incinerator outlet gas exhausts to the atmosphere via a stack.

The actual gas flowrate through the incinerators at Plant C-1 is relatively constant for different products. However, the inlet VOC mass flowrate and the VOC type vary from one product to the next.

Incinerator 28 handles a SLA flowrate of approximately 3.2 Nm^3/s at 89°C (6780 scfm at 190°F) and incinerator 27 handles 3.6 Nm^3/s at 121°C (7,600 scfm at 250°F). Based on THC measurements, inlet solvent mass flowrates for the two incinerators ranged from 13 to 44 kg/hr (29 to 97 lb/hr), depending on the product being made. Actual solvent usage rates were not monitored during the testing.

The incinerators tested at Plant C-1 were designed and manufactured by DuPont and had a destruction efficiency guarantee of 90 percent. The catalyst in the incinerators is a catalyst coated ceramic honeycomb with the trade name Torvex^R. Each incinerator contains 0.33 m^3 (12 ft^3) of catalyst, giving a SLA residence time of approximately 0.03 seconds.

Incinerator 28 was started up in December 1980 and the original catalyst was replaced on November 13, 1982. Incinerator 27 began operation in March 1982 and still had the original catalyst when the plant was tested in November 1982.

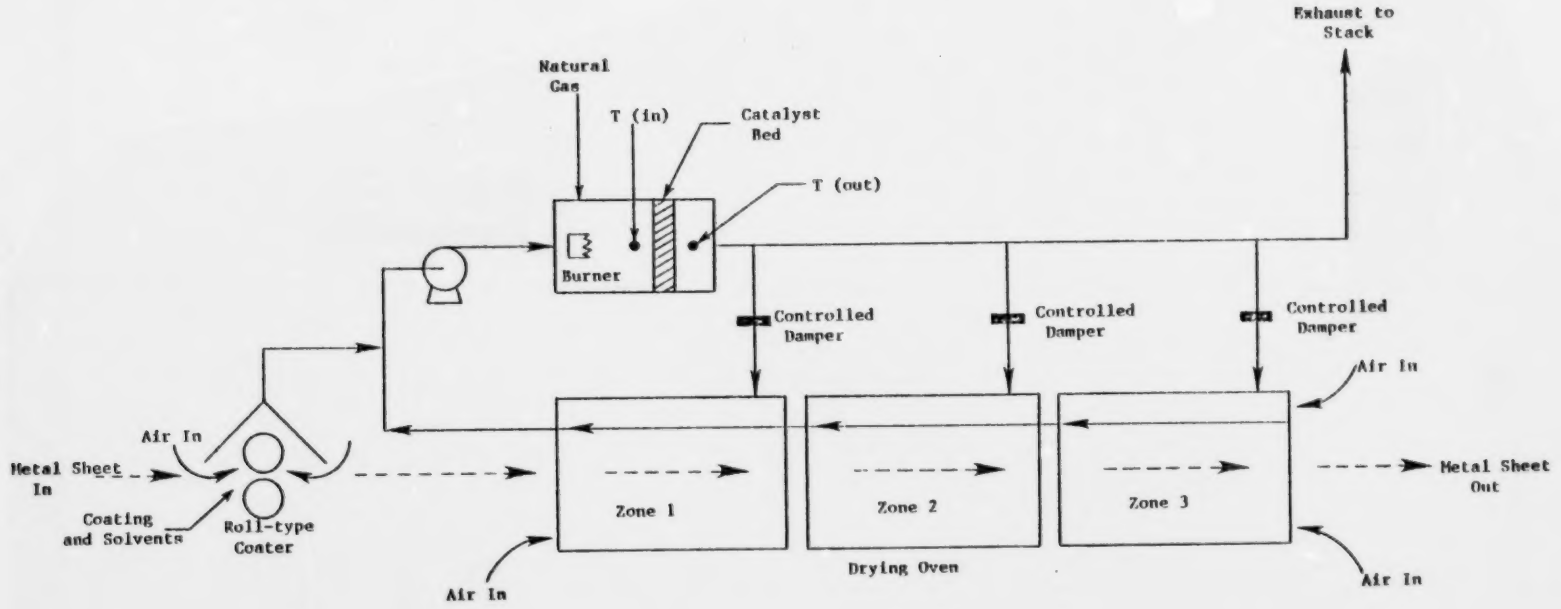

Figure 4-1. Process flow diagram for Plant C-1.

4.2 PLANT C-2

Plant C-2 produces graphic arts (magazines, brochures, etc.) by web offset printing. The inks used in the printing consist of pigments borne in a heavy organic solvent of C_{12} through C_{18} hydrocarbons. After the ink is applied to the paper web, the solvent is driven off in a gas-fired drying oven, leaving the pigments on the web. Oven exhaust gas is ducted to a catalytic incinerator for solvent destruction.

The incinerator tested at Plant C-2 is used to destroy solvent emissions from the drying oven on a single printing line. In addition to the drying oven exhaust gas, fugitive VOC emissions from the cooling zone immediately following the drying oven are captured with a hood and ducted to the incinerator.

A flow diagram illustrating the oven and incinerator configuration at Plant C-2 is given in Figure 4-2. As shown in Figure 4-2, solvent laden air (SLA) is drawn from the oven and cooling zone by a blower and ducted to the burner zone of the incinerator. The SLA is heated by the combustion of natural gas and then passes through the catalyst bed where solvents are oxidized.

The incinerator at Plant C-2 handles a SLA flowrate of approximately 0.9 Nm^3/s (2,000 scfm) at 101°C (215°F)and was designed by Matthey-Bishop with a design destruction efficiency of 90 percent. The ceramic catalyst in the incinerator is arranged in a honeycomb configuration. The total catalyst volume is 0.09 m^3 (3 ft^3), giving a SLA residence time of approximately 0.02 seconds.

The incinerator at Plant C-2 was started up in 1975. Initially the incinerator was believed to have logged only 2000 hours of operating time prior to testing in December 1982. This was later found to be considerably in error and the actual number of operating hours logged is not known.

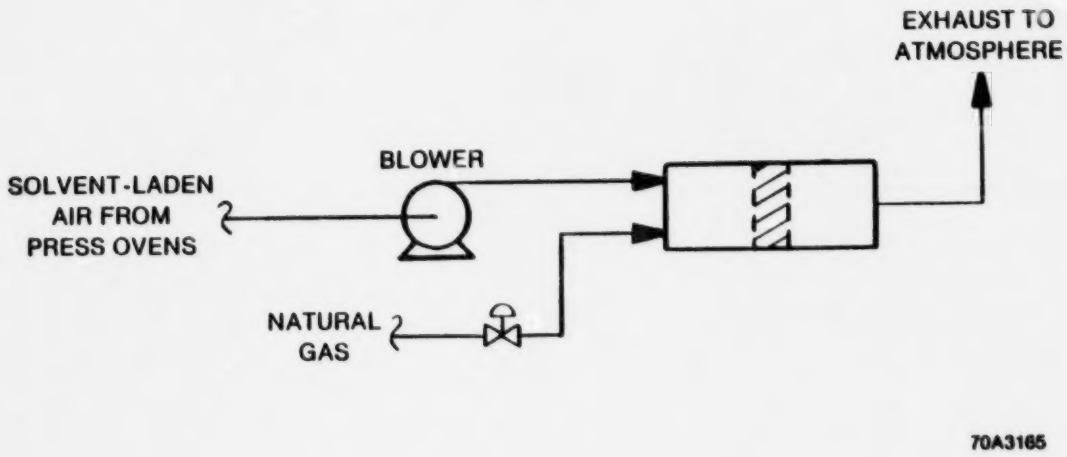

Figure 4-2. Plant C-2 catalytic incinerator flow diagram.

4.3 PLANT C-3

Plant C-3 produces graphic arts, primarily magazines and brochures, by web offset printing. Inks consisting of pigments borne in a heavy organic solvent of C_{12} through C_{18} hydrocarbons are applied to a paper web. The printed web passes through a drying oven where the solvent is evaporated. Oven exhaust gas containing vaporized solvent is ducted to a catalytic incinerator for VOC control.

Two incinerators, incinerators 20 and 21, were tested at Plant C-3. Incinerator 20 handles oven exhaust from a single printing line while incinerator 21 handles oven exhaust from two printing lines. The ink applied by the presses consists of colored pigments borne in a heavy organic solvent consisting of C_{12} through C_{18} organics with an average molecular weight of approximately 210 g/g-mole. Exact composition of the solvent is unknown.

Incinerators 20 and 21 are described separately below.

Incinerator 20--

A schematic diagram of the relationship between the oven and incinerator on printing line 20 is given in Figure 4-3. As shown in Figure 4-3, oven exhaust containing vaporized solvent is delivered by a single blower to the incinerator. The SLA is preheated by an integral heat exchanger which extracts heat from the incinerator exhaust gas, and then passes to the burner zone of the incinerator. The SLA is further heated by the combustion of natural gas and then passes through the catalyst bed where solvents in the SLA are oxidized. The combustion products are then cooled in the SLA preheater and exhausted to the atmosphere. Heat recovery is estimated to be 35 percent.

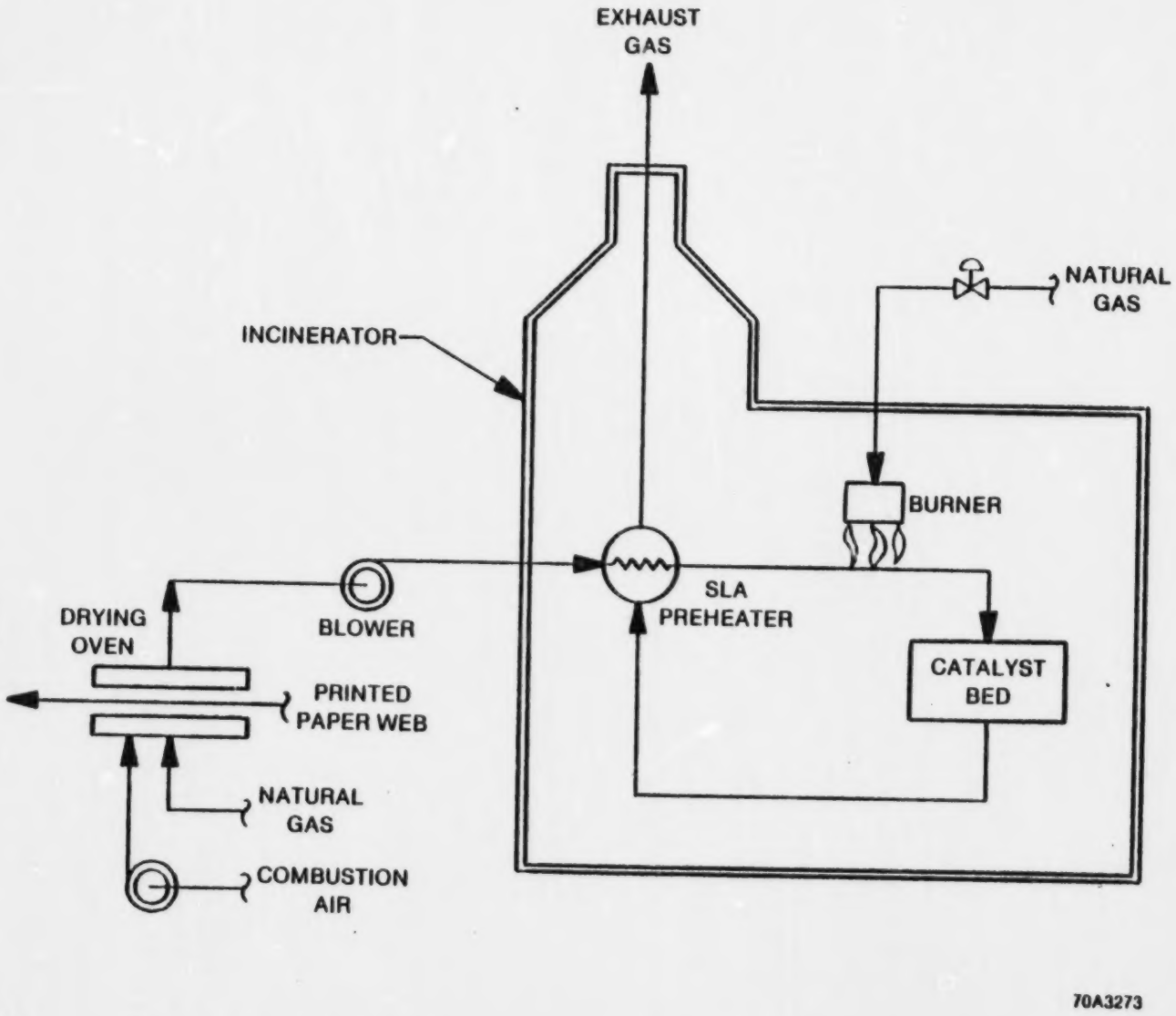

Figure 4-3. Process flow diagram for Incinerator 20 - Plant C-3.

Incinerator 20 handles a SLA flowrate of approximately 1.3 Nm^3/sec at 177°C (2,660 scfm at 350°F). The incinerator was designed and manufactured by TEC Systems. The catalyst consists of alumina-based pellets coated with oxides of copper, manganese, and trace amounts of palladium. The total catalyst volume is 0.302 m^3 (10.7 ft^3). Assuming a void fraction within the bed of 40 percent, the SLA residence time is 0.04 seconds.

Incinerator 20 was started up in February 1980 and the original catalyst was replaced in September 1981. The incinerator was tested in January 1983.

Incinerator 21--

A schematic diagram of the oven and incinerator on printing line 21 is shown in Figure 4-4. As shown in Figure 4-4, pressroom air is drawn into the system by a blower and is preheated in a heat exchanger which extracts heat from the incinerator exhaust gas. The heated air enters the two gas-fired drying ovens (press 21 has dual printing lines) and evaporates solvent on the printed web. The SLA is then further heated in a second heat exchanger and by the combustion of natural gas in the burner zone upstream of the catalyst chamber. The incinerator exhaust gas then exits the catalyst chamber, is cooled in the two heat exchangers mentioned above, and is discharged to the atmosphere. Heat recovery is estimated to be 60 percent.

Incinerator 21 handles a SLA flowrate of approximately 2.2 Nm^3/s at 178°C (4,670 scfm at 352°F) and was designed and manufactured by TEC Systems. The catalyst consists of alumina-based pellets coated with oxides of copper, manganese, and trace amounts of palladium. The total catalyst volume is 0.491 m^3 (17.3 ft^3). Assuming a void fraction within the bed of 40 percent, the SLA residence time is approximately 0.04 seconds.

Incinerator 21 was started up in April 1982 and the original catalyst was in place during the testing in January 1983.

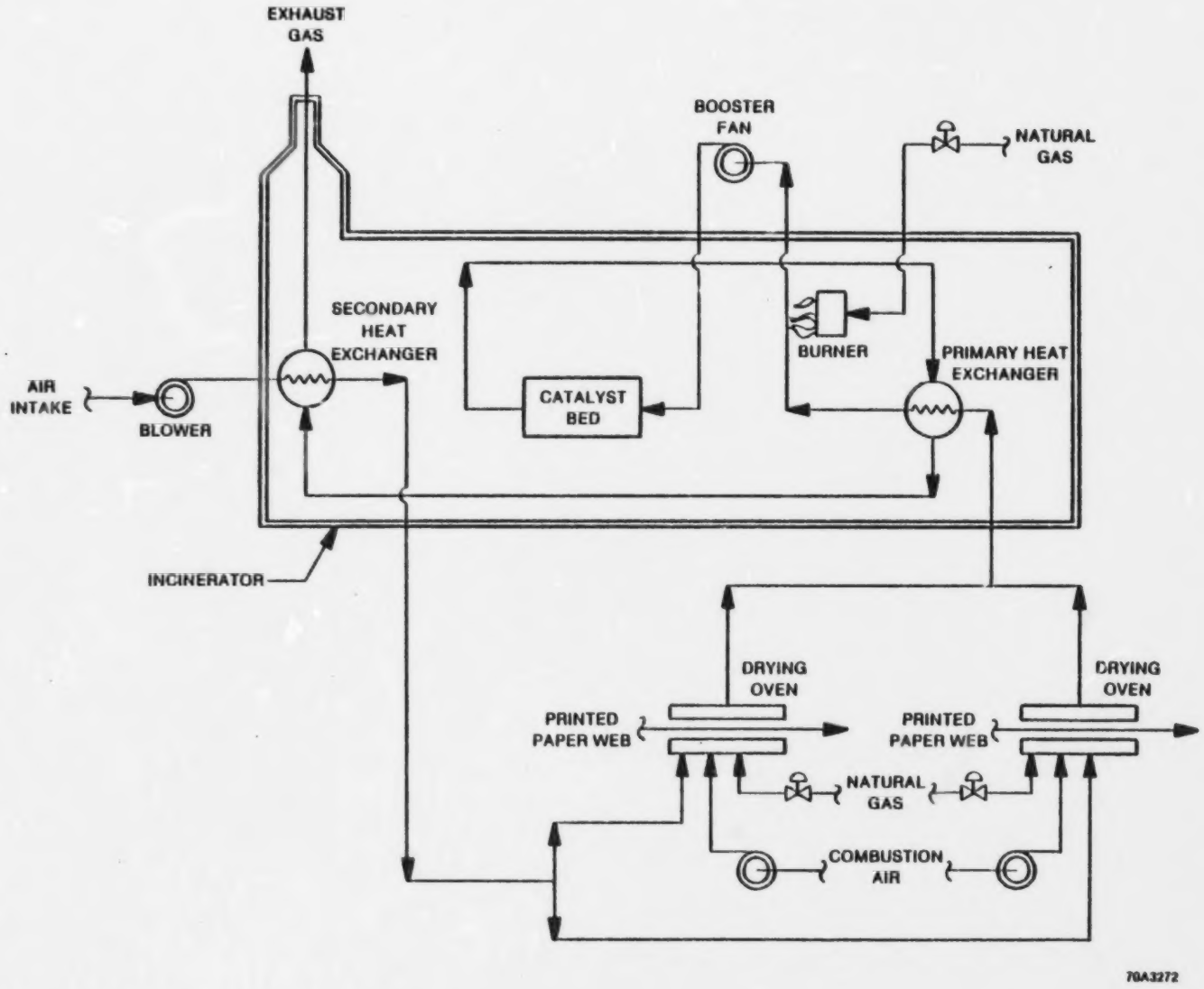

Figure 4-4. Process flow diagram for Incinerator 21 - Plant C-3.

4.4 PLANT C-4

Plant C-4 is a manufacturer of decorative metal cans and falls under SIC 3411, the metal can industry. In this process, coatings and pigments are applied to metal sheets in thin coats. The solvents are then driven off the metal sheets in drying ovens and the oven exhaust is ducted to a catalytic incinerator for solvent destruction.

The incinerator tested at Plant C-4 is used to destroy solvent emissions from a single sheet metal coating line. Coated metal sheets pass through five oven zones in addition to one preheat zone. Volatilized solvents are drawn from the various oven zones by a large fan through a common duct to the incinerator. In addition, fugitive VOC emissions resulting from the roll-type coating applicator operation are captured by a hood and ducted to the incinerator.

Coatings used at Plant C-4 are purchased pre-mixed from coating manufacturers. Solvents identified in the coatings include methyl isobutyl ketone (MIBK), cellosolve, xylenes and ethyl benzenes.

A schematic diagram illustrating the relationship between the drying oven and incinerator at Plant C-4 is given in Figure 4-5. As shown in Figure 4-5, solvent laden air (SLA) drawn from the oven by a large blower passes through the burner zone of the incinerator. The SLA is heated by the combustion of natural gas and then passes through the catalyst bed where solvents in the SLA are oxidized. The incinerator outlet gas exhausts to the atmosphere through a stack.

The incinerator handles a SLA flowrate of approximately 2.5 Nm^3/s at 164°C (5,330 scfm at 327°F). Based on measured THC concentrations, the inlet solvent mass flowrate ranged from 11 to 34 kg/hr (25 to 75 lb/hr), depending on the product type and size. Actual solvent usage rates were not monitored during the testing.

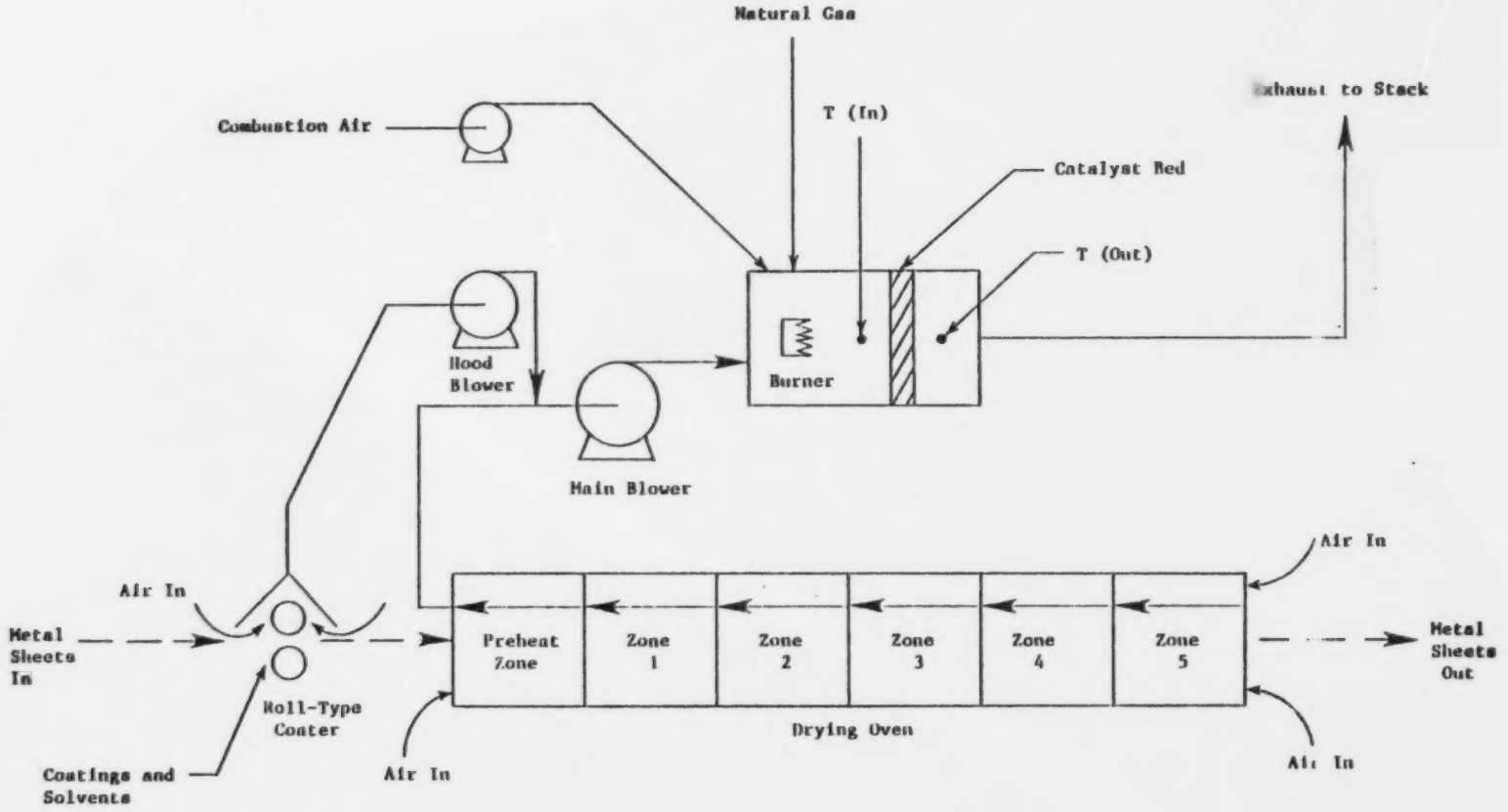

Figure 4-5. Process flow diagram for Plant C-4.

The incinerator at Plant C-4 is a Maxom fume burner retrofitted with a DuPont Torvex^{R} honeycomb catalyst bed. The total catalyst volume is 0.28 m^3 (10 ft^3), giving a SLA residence time of approximately 0.03 second.

The incinerator at Plant C-4 was retrofitted with a catalyst bed in March 1982 and the original catalyst was in place during testing in February 1983. However, in September 1982, the catalyst was temporarily removed from the incinerator and cleaned with an alkaline solution. The catalyst had become masked from operation at a lower than optimum catalyst bed inlet temperature.

4.5 PLANT C-5

Plant C-5 produces magnet wire by coating bare copper wire with an electrically insulating enamel (SIC 33577). The wire is coated with a thin coat of resins dissolved in phenol and cresols. The coated wire passes through a drying oven where the solvents evaporate and the resins cure. The exhaust from the oven is ducted to a catalytic incinerator for solvent destruction.

A schematic diagram of the coating process and the catalytic incinerator at Plant C-5 is shown in Figure 4-6. As shown in Figure 4-6, solvent laden air (SLA) is drawn from the drying oven by a blower and passes into the burner zone of the incinerator. The gas is heated in the burner to approximately 399°C (750°F) by the combustion of a 9:1 air/fuel mixture. The hot gas then passes through the catalyst bed where the solvents are oxidized. All of the outlet gas from the incinerator is exhausted to the atmosphere via a stack.

The SLA gas flowrate at the incinerator inlet is approximately 0.28 Nm^3/s at 233°C (603 scfm at 450°F). The inlet gas flowrate remains constant during normal operation. However, the inlet solvent mass flowrate varies with the type of coating, the number of wires, the wire diameter and the line speed.

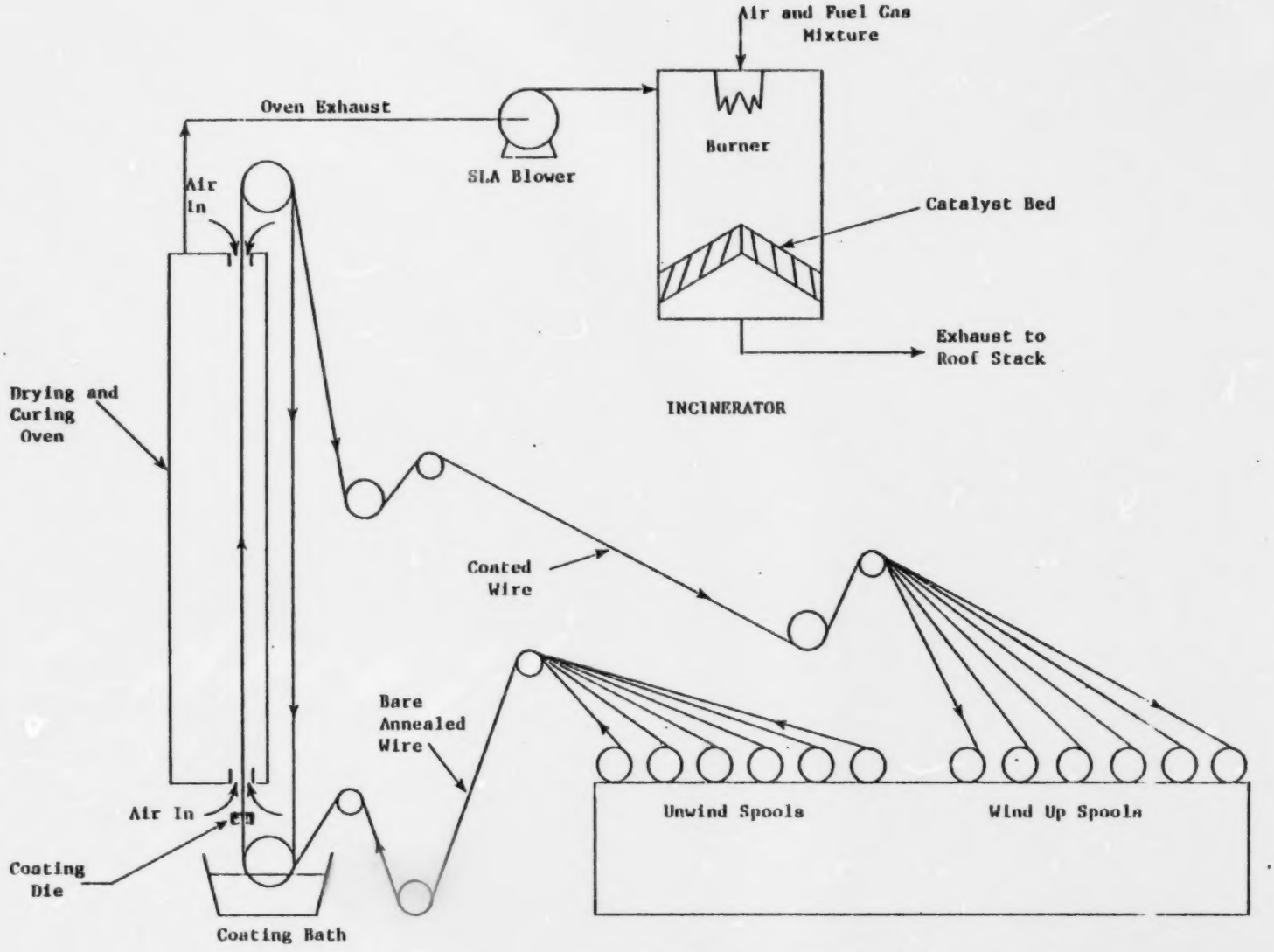

Figure 4-6. Process flow diagram for Plant C-5.

The incinerator tested at Plant C-5 was originally designed and manufactured by OxiCatalyst Incorporated (circa 1965) and was later modified by the plant. The modification involved switching from a ceramic-based catalyst to a metal-based catalyst. Further, the catalyst bed configuration was changed to increase the catalyst volume. Originally, the catalyst bed was perpendicular to the gas flow and not angled in the manner shown in Figure 4-6.

The catalyst tested consists of catalyst coated metal ribbon with a catalyst bed volume of 0.024 m^3 (0.83 ft^3). Assuming a void fraction of 40 percent, the SLA residence time is approximately 0.015 second. A recently rejuvinated catalyst bed was in place during the testing in February 1983.

4.6 PLANT C-6

Plant C-6 produces coated aluminum foil for use in the food packaging industry and falls under SIC 3497, the metal foil and leaf industry. In this coil coating process, aluminum foil is unwound from a coil and passed through a coating applicator where pigments dissolved in solvents are applied to the foil. The solvents are then driven off the foil in a drying oven and the coated foil is recoiled. The exhaust from the coating oven is ducted to a catalytic incinerator for solvent destruction.

The incinerator tested at Plant C-6 is used to destroy solvent emissions from a two-side coil coating line. The coating line is actually two coaters in series, with one coating station and drying oven for each side of the foil. For two-side coating, the foil must be passed through each coating station and its corresponding drying oven. Solvent emissions from only one of the coating stations and drying ovens are destroyed in the incinerator. Emissions from the other oven are currently not abated because this section of the oven is used infrequently.

In addition to the exhaust from the oven, fugitive VOC emissions from the coating area are also ducted to the incinerator. The fugitive emissions are captured with "floor sweeps" located on each side of the coating applicator.

The coatings used at Plant C-6 contain mostly toluene and methyl ethyl ketone (MEK). However, some of the coatings also contain xylenes, isopropyl alcohol, n-butyl alcohol and/or cellosolve acetate. Based on plant data, solvent usage rates averaged approximately 77 kg/hr (170 lb/hr) during the testing.

A process flow diagram showing the incinerator and coil coater is given in Figure 4-7. For simplicity, Figure 4-7 shows only one drying oven and coating applicator. Emissions from the other oven and coating applicator are not ducted to the incinerator tested.

As shown in Figure 4-7, a large blower draws solvent laden air (SLA) from the first two oven zones and from the floor sweeps. The SLA passes into the burner zone of the incinerator where it is heated to 288°C (550°F) by the combustion of natural gas. A portion of the floor sweep gas serves as the combustion air for the burner.

The hot gas from the burner zone passes first through a high temperature filter for particulate removal and then through the catalyst bed for solvent destruction. Approximately 50 percent of the incinerator outlet gas, typically at 399 to 427°C (750 to 800°F), and a portion of the floor sweep gas are recirculated to the first two zones of the oven. Dampers control the amount of air recirculated to maintain a preset oven zone temperature. This zone temperature varies with the coating being dried. The rest of the incinerator outlet gas exhausts to the atmosphere via a stack. Heat recovery is estimated to range from 25 to 36 percent, depending on the operating temperature.

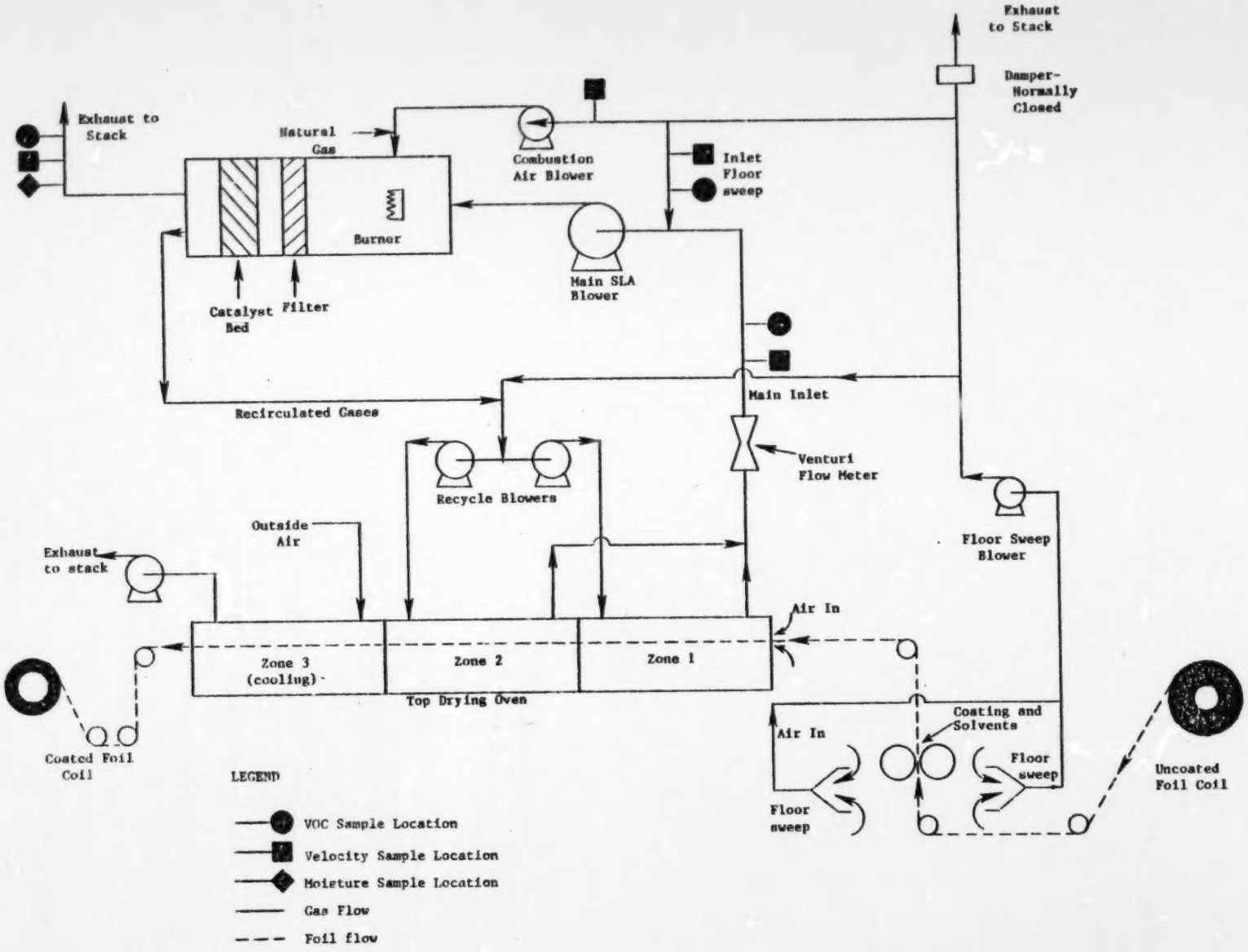

Figure 4-7. Process flow diagram for Plant C-6.

Figure 4-7. Process flow diagram for Plant C-6.

The cooling zone of the oven uses outside ambient air to cool the coated foil before it is recoiled. The exhaust from the cooling zone of the oven is vented back outside and does not pass through the incinerator.

The gas flowrate of SLA from the drying oven is constant for different coatings or products. The inlet solvent concentration and the solvent type vary from one product to the next.

The incinerator at Plant C-6 handles an inlet SLA flowrate of approximately 5.33 m^3/s at 149°C (11,300 scfm at 300°F). The incinerator was designed and manufactured by DuPont and had a destruction efficiency guarantee of 95 percent. The catalyst in the incinerator is a catalyst coated ceramic honeycomb with the trade name Torvex^R. The total catalyst volume is 0.50 m^3 (17.5 ft^3), giving a SLA residence time of approximately 0.03 seconds.

The incinerator began operation on January 24, 1983 and had the original catalyst at the time of testing in March 1983.

SECTION 5

TESTING PROCEDURES

Testing procedures followed during the performance evaluations of catalytic incinerators at Plants C-1 through C-6 are presented in this section. In most cases, sampling and analytical procedures were based on EPA reference methods. However, in some instances, non-reference methods or modifications of reference methods were needed. Section 5.1 describes the various sampling and analytical methodologies used to evaluate the performance of catalytic incinerators at Plants C-1 through C-6. In Section 5.2, sampling and analytical procedures matrices are presented for Plants C-1 through C-6.

5.1 SAMPLING AND ANALYTICAL METHODS

In order to characterize operation and volatile organic compound (VOC) destruction efficiency of the incinerators at Plants C-1 through C-6, the following analyses were performed:

- VOC analyses
- Carbon monoxide (CO) analyses
- Fixed gas analysis (for molecular weight determination)
- Moisture content determination
- Velocity/volumetric flowrate determination

In addition, other process data including operating temperatures, pressures, fuel usage, etc., were measured or monitored during testing to further characterize incinerator operation. The various sampling and analytical methodologies used for each analysis are briefly described in the following

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subsections. A more detailed discussion of sampling and analytical procedures are found in the Interim Test Reports for Plants C-1 through C-6.

5.1.1 VOC Analyses

Three analytical procedures were used at Plants C-1 through C-6 to measure VOC concentration and to identify solvent components in the incinerator inlet and outlet gas streams. Total hydrocarbon (THC) analyses were performed on each incinerator based on EPA Proposed Reference Method 25A[1]. This was the primary method used to determine incinerator destruction efficiency. In addition, speciation of the inlet and outlet gas streams by gas chromatography (GC) was performed according to EPA Draft Reference Method 18[2]. Finally, samples for gas chromatography/mass spectrometry (GC/MS) analyses were taken at each incinerator tested to identify solvent components in the sampled gas streams.

Sampling and analytical procedures used in each analysis are described below.

Method 25A Analyses--

Both the incinerator inlet and outlet gas streams were continuously sampled. A three-hole sampling rake was used to extract the gas sample from the main gas stream. As required by Method 25A specifications, the sampling rake had holes 3.2 mm (1.8 in) in diameter drilled in the tubing at a relative location of 16.7, 50 and 83.3 percent of the equivalent duct diameter. Sample gas passed through 6 feet of heat-traced stainless steel line and a heated (205°C, 400°F) sampling pump before entering a heat-traced Teflon^{R} umbilical that carried it to the mobile laboratory. During transport through the umbilical from the duct to the laboratory, the sample gas was maintained at a sufficiently high temperature to prevent condensation of organic components. Required umbilical temperatures varied for each incinerator depending on the composition of the sampled gas streams.

A manifold system inside the mobile laboratory was used to split the sample streams for analysis in two types of instruments, a THC analyzer and an organic species analyzer. A schematic of the typical sampling arrangement for measurement of VOC concentration is shown in Figure 5-1.

Method 25A specifies that THC determinations be performed using a continuous monitor equipped with a flame ionization detector (FID). Although an FID was used for the testing, monitoring was performed on a semi-continuous basis. The FID response was calibrated against propane standards. Three different instruments were used to measure THC concentrations in the incinerator inlet and outlet gas streams.

In most cases, inlet gas stream samples were analyzed by a Byron 301, THC analyzer. The Byron Model 301 Hydrocarbon Analyzer is a non-specific process gas chromatograph (GC) utilizing an FID to quantitatively determine methane (CH_4) and non-methane hydrocarbons in the vapor phase. In cases where the incinerator inlet stream contained high concentrations of high molecular weight organic compounds, a modified Tracor 560 gas chromatograph was used. In order to convert the Tracor 560 GC to an automated THC analyzer, the GC was modified to introduce gas samples directly to the FID and to inject samples automatically at 10 minute intervals.

Incinerator outlet gas samples were analyzed by a Byron 401 THC analyzer. The Byron Model 401 Total Emissions Analyzer is similar to the model 301. The 401 has the additional capability of analyzing a sample stream for total hydrocarbons (THC), nonmethane hydrocarbons, carbon dioxide (CO_2), methane, and carbon monoxide (CO). During the testing, the instrument was operated mostly in the THC only mode because the one minute cycle time allowed measurement of relatively rapid concentration changes. The full scan mode was operated for brief periods to obtain measurements of CO and CH_4 in the outlet gas.

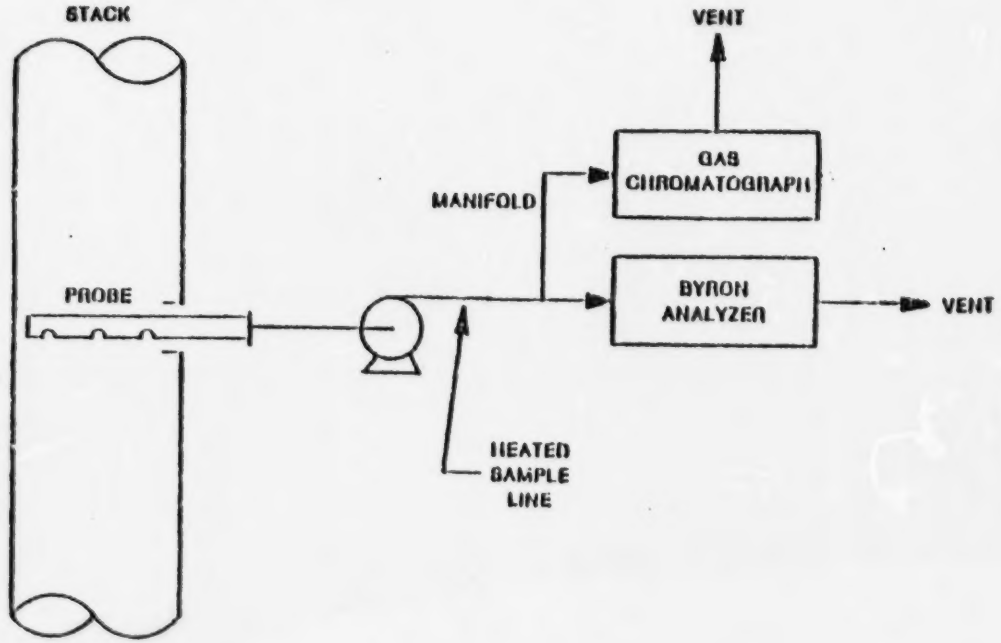

Figure 5-1. Sample acquisition system for VOC analyses.

Method 18 Analysis--

Sample acquisition for GC analysis was performed by the same sampling system used for THC analysis. As discussed, a manifold system inside the mobile laboratory was used to split the inlet and outlet sample streams for THC and GC analysis.

Draft Method 18 provides for the individual quantitation of organic species by gas chromatography using an FID. Two GC instruments were used during testing in a Hewlett Packard Model 5730A and an Antek Model 460. GC analyses were performed simultaneously with THC analyses wherever possible.

GC/MS Analysis--

Samples for GC/MS analysis were acquired from two sources. For some incinerators, samples for GC/MS analysis were acquired at the outlet of the sample acquisition system described above using evacuated canisters. The canisters were cleaned, evacuated, and the absolute pressure recorded before sampling. Immediately prior to sampling, canister pressure was remeasured to ensure that no leakage had occurred. Flow regulators were used to provide a constant flow over the 20-minute sampling period.

A second source of GC/MS samples at some incinerators was the impinger water from the moisture train. Hot outlet gas dissolves in the chilled impinger water, as evidenced by a color change. Samples of water from the first impinger were collected in clean sample bottles for GC/MS analysis.

All GC/MS analyses were performed by Radian's Austin laboratories. These analyses provided identification of various organic species in the sampled gas streams.

5.1.2 CO Analysis

CO concentrations of the incinerator exhaust gas were periodically measured by the Byron 401 THC Analyzer operating in the "Full Scan" (FS) mode. Sample acquisition occurred via the sampling system described in

Section 5.1.1. In the FS mode, a portion of the gas sample is introduced directly to the FID, yielding a THC measurement. Subsequently, nonmethane hydrocarbons (NMHC), CH_4, CO_2, and CO are chromatographically separated from the balance of the gas sample. One at a time, each of these groups is passed through an oxidizer/reducer to convert all carbon to CH_4. These reduced streams are then individually introduced to the FID for measurement, with a complete cycle requiring 12 minutes.

5.1.3 Fixed Gas Analysis

Two EPA Reference Method 3 equivalents were used to determine the dry (M_d) and wet (M_w) molecular weight of the incinerator inlet and outlet gas streams.[3]

In the first method, rather than collecting integrated or grab samples of the gas stream, the umbilical and manifold system described in Section 5.1.1 was used to acquire samples for fixed gas (CO_2, O_2, and N_2). After the sample stream passed through the organic species analyzer, it entered a set of impingers to knock out moisture and heavy organics. The cool, dry gas then proceeded through a Fisher Model 1200 Gas Partitioner for fixed gas analysis. The Fisher Gas Analyzer employs dual thermal conductivity detectors to determine the concentrations of fixed gases in a sample stream.

The second method of fixed gas analysis required two instruments. An oxygen Fyrite apparatus was used to determine oxygen content of the incinerator outlet stream. Gas sample for oxygen analysis was drawn directly from the outlet sampling port. The carbon dioxide content of the outlet stream was measured using the Byron 401 analyzer in the full scan mode. Gas sample for CO_2 analysis was drawn from the Method 25A sampling manifold. The nitrogen content of the outlet stream was determined by difference. For both methods, the dry molecular weight of the inlet and outlet gas was

calculated based on the concentrations of the fixed gases and converted to a wet basis using Method 4 moisture data.

5.1.4 Moisture Content Determination

The moisture content of the incinerator inlet and outlet gas streams was determined using the methodology prescribed in EPA Reference Method 4. Based on this method, a measured volume of particulate-free gas is pulled through an impinger train.[4] Figure 5-2 graphically illustrates the sampling train which was used for moisture determination. The quantity of water condensed in the impingers is determined gravimetrically and then related to the volume of gas sampled to determine the moisture content.

5.1.5 Velocity/Volumetric Flowrate Determination

The volumetric gas flowrate of the incinerator inlet and outlet streams was measured using procedures described in EPA Methods 1 and 2 velocity of the flue gas.[5,6] The average gas velocity was calculated from the average gas velocity pressure (ΔP), the average flue gas temperature, wet molecular weight, and the absolute pressure in the stack. Temperature and ΔP, profiles were obtained by traversing the stack.

Temperature profile and ΔP data were collected at each of the sampling points using a K-type thermocouple and an S-type pitot tube. A gauge oil manometer was used to measure the pressure drop (ΔP) across the S-type pitot. The daily barometric pressure was obtained from a local weather station and corrected for evaluation.

For some incinerators, the volumetric gas flowrate of the incinerator inlet could not be measured according to EPA Method 2 because no acceptable sampling location was available. The inlet gas flowrate was calculated using the measured outlet gas flowrate and estimated combustion air and fuel gas flowrates.

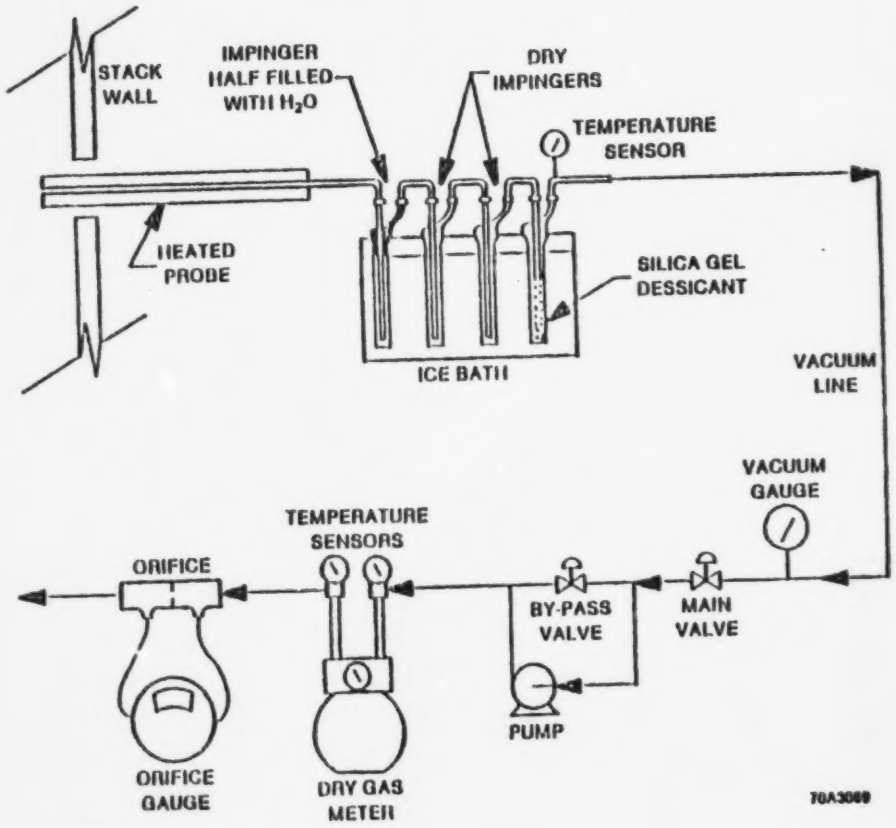

Figure 5-2. EPA Method 4 moisture train.

5.1.6 Other Process Data

In addition to VOC concentrations, CO concentrations, stream molecular weights and volumetric flowrates, several process parameters were measured or monitored at various points in the incinerators. These parameters included pressure drops across each stage of the system, operating temperatures, and combustion air and fuel parameters. In some instances, these data were obtained from plant instrumentation.

5.2 SAMPLING AND ANALYTICAL PROCEDURES MATRICES

A summary of the specific sampling and analytical procedures used during performance testing at Plants C-1 through C-6 are presented in Tables 5-1 to 5-6.

TABLE 5-1. SAMPLING AND ANALYTICAL PROCEDURES MATRIX - PLANT C-1

Measurement Parameter	Sampling Procedure	Analytical Procedure	Reference
VOC Concentration (THC)	Rake-type probe, heated sampling line (100°C (212°F))	FID-based THC analyzers	EPA Proposed Reference Method 25A
VOC Concentration (Speciated)	Rake-type probe, heated sampling line (100°C (212°F))	FID-based gas chromatograph	EPA Draft Reference Method 18
VOC Species Identification	Rake-type probe, heated sampling line (100°C (212°F)), evacuated canisters	GC/MS	--
CO Concentration	Rake-type probe, heated sampling line (100°C (212°F))	FID-based analyzer with with species separation and oxidation/reduction to methane.	
Molecular Weight (Fixed Gases)	Rake-type probe, heated sampling line (100°C (212°F)	TCD-based analyzer	EPA Reference Method 3 (Equivalent)
Moisture Content	Goose-neck probe, chilled impinger train	Gravimetric determination of condensate, measurement of sampled gas volume	EPA Reference Method 4
Velocity/Volumetric Flow Rate	S-type pitot tube	Calculations based on velocity, pressure, temperature	EPA Reference Methods 1 and 2
Process Data	Plant instrumentation	--	--

VOC = volatile organic compound
THC = total hydrocarbon
FID = flame ionization detector
GC/MS = gas chromatography/mass spectrometry
CO = carbon monoxide
TCD = thermal conductivity detector

TABLE 5-2. SAMPLING AND ANALYTICAL PROCEDURES MATRIX - PLANT C-2[a]

Measurement Parameter	Sampling Procedure	Analytical Procedure	Reference
VOC Concentration (THC)	Rake-type probe, heated sampling line (145°C (293°F))	Inlet-modified FID-based gas gas chromatograph; outlet-FID-based THC analyzer	EPA Proposed Reference Method 25A
CO Concentration	Rake-type probe, heated sampling line (145°C (293°F))	FID-based analyzer with species separation and oxidation/reduction to methane	--
Molecular Weight (Fixed Gases)	Rake-type probe, heated sampling line (145°C (293°F))	TCD-based analyzer	EPA Reference Method 3 (Equivalent)
Velocity/Volumetric Flow Rate	S-type pitot tube	Calculations based on velocity, pressure, temper-	EPA Reference Methods 1 and 2
Process Data	Plant Instrumentation	--	--

[a]GC, GC/MS, and moisture samples were not taken because the catalyst was found to be deactivated (see Section 6.1).

TABLE 5-3. SAMPLING AND ANALYTICAL PROCEDURES MATRIX - PLANT C-3

Measurement Parameter	Sampling Procedure	Analytical Procedure	Reference
VOC Concentration (THC)	Rake-type probe, heated sampling line (145°C (293°F))	Inlet: modified FID-based gas chromatograph; outlet: FID-based THC analyzer	EPA Proposed Reference Method 25A
VOC Concentration (Speciated)	Rake-type probe, heated sampling line	FID-based gas chromatograph	EPA Draft Reference Method 18
VOC Species Identification	Rake-type probe, heated sampling line (145°C (293°F)); evacuated canisters for light organics, impinger condensate for heavy organics	GC/MS	--
CO Concentration	Rake-type probe, heated sampling (145°C (293°F))	FID-based analyzer with species separation and oxidation/reduction to methane	--
Molecular Weight (Fixed Gases)	Rake-type probe, heated sampling line (145°C (293°F))	TCD-based analyzer	EPA Reference Method 3 (Equivalent)
Moisture Content	Goose-neck probe, chilled impinger train	Gravimetric determination of condensate, measurement of sampled gas volume	EPA Reference Method 4
Velocity/Volumetric Flowrate	S-type pitot tube	Calculations based on velocity pressure, temperture	EPA Reference Methods 1 and 2
Process Data	Plant instrumentation	--	--

VOC = volatile organic compound
THC = total hydrocarbon
FID = flame ionization detector
GC/MS = gas chromatography/mass spectrometry
CO = carbon monoxide
TCD = thermal conductivity detector

TABLE 5-4. SAMPLING AND ANALYTICAL PROCEDURES MATRIX - PLANT C-4

Measurement Parameter	Sampling Procedure	Analytical Procedure	Reference
VOC Concentration (THC)	Rake-type probe, heated sampling line (100°C (212°F))	FID-based THC analyzers	EPA Proposed Reference Method 25A
VOC Concentration (Speciated)	Rake-type probe, heated sampling line (100°C (212°F))	FID-based gas chromato-	EPA Draft Reference Method 18
VOC Species Identification	Rake-type probe, heated sampling line (100°C, (212°F)), evacuated canisters	GC/MS	--
CO Concentration	Rake-type probe, heated sampling line (100°C (212°F))	FID-based analyzer with species separation and oxidation/reduction to methane	--
Molecular Weight (Fixed Gases)	Rake-type probe, heated sampling line (100°C (212°F))	TCD-based analyzer	EPA Reference Method 3 (Equivalent)
Moisture Content	Goose-neck probe, chilled impinger train	Gravemetric determination of condensate, measurement of sampled gas volume	EPA Reference Method 4
Velocity/Volumetric Flow Rate	S-type pitot tube	Calculations based on velocity, pressure, temperature	EPA Reference Methods 1 and 2
Process Data	Plant instrumentation	--	--

VOC = volatile organic compound
THC = total hydrocarbon
FID = flame ionization detector
GC/MS = gas chromatography/mass spectrometry
CO = carbon monoxide
TCD = thermal conducitivity detector

TABLE 5-5. SAMPLING AND ANALYTICAL PROCEDURES MATRIX - PLANT C-5

Measurement Parameter	Sampling Procedure	Analytical Procedure	Reference
VOC Concentration (THC)	Rake-type probe, heated sampling line (138°C (280°F))	Inlet: modified FID-based gas chromatograph; outlet: FID-based THC analyzer	EPA Proposed Reference Method 25A
VOC Concentration (Speciated)	Rake-type probe, heated sampling line (138°C (280°F))	FID-based gas chromatograph	EPA Draft Reference Method 18
VOC Species Identification	Rake-type probe, heated sampling line (138°C (280°F)); evacuated canisters for light organics, impinger, condensate for heavy organics	GC/MS	--
CO Concentration	Rake-type probe, heated sampling line (138°C (280°F))	FID-based analyzer with species separation and oxidation/reduction to methane	--
Molecular Weight (Fixed Gases)	O_2-gas sample drawn directly from outlet sampling port; CO_2 - rake-type probe, heated sampling line (138°C (280°F))	O_2-oxygen Fyrite apparatus; CO_2 - FID-based analyzer with species separation and oxidation/reduction to methane	EPA Reference Method 3 (Equivalent)
Moisture Content	Goose-neck probe, chilled impinger train	Gravimetric determination condensate, measurement of sampled gas volume	EPA Reference Method 4
Velocity/Volumetric Flowrate	S-type pitot tube	Calculations based on velocity, pressure, temperature	EPA Reference Methods 1 and 2
Process Data	Plant instrumentation	--	--

VOC = volatile organic compound
THC = total hydrocarbon
FID = flame ionization detector
GC/MS = gas chromatography/mass spectrometry
CO = carbon monoxide

TABLE 5-6. SAMPLING AND ANALYTICAL PROCEDURES MATRIX - PLANT C-6

Measurement Parameter	Sampling Procedure	Analytical Procedure	Reference
VOC Concentration (THC)	Rake-type probe, heated sampling line (100°C (212°F))	FID-based THC analyzers	EPA Proposed Reference Method 25A
VOC Concentration (Speciated)	Rake-type probe, heated sampling line (100°C (212°F))	FID-based gas chromatograph	EPA Draft Reference Method 18
VOC Species Identification	Rake-type probe, heated sampling line (100°C (212°F)), evacuated canisters	GC/MS	--
CO Concentration	Rake-type probe, heated sampling line (100°C (212°F))	FID-based analyzer with species separation and oxidation/reduction to methane	--
Molecular Weight (Fixed Gases)	O_2-gas sample drawn directly form outlet sampling port; CO_2 - rake-type probe heated sampling line (100°C (212°F))	O_2 - oxygen Fyrite CO_2 - FID-based analyzer with species separation and oxidation/reduction to methane	EPA Reference Method 3
Moisture Content	Goose-neck probe, chilled impinger train	Gravimetric determination of condensate, measurement of sampled gas volume.	EPA Reference Method 4
Velocity/Volumetric Flowrate	S-type pitot tube	Calculations based on velocity, pressure, temperature	EPA Reference Methods 1 and 2
Process Data	Plant instrumentation	--	--

VOC = volatile organic compound
THC = total hydrocarbon
FID = flame chromatography/mass spectrometry
CO = carbon monoxide
TCD = thermal conductivity detector

SECTION 5 REFERENCES

1. EPA Proposed Method 25A, "Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer," Proposed Revision to Appendix A 40 CFR, Federal Register, Volume 45, Number 194, December 17, 1980. pp. 83149-83151.

2. EPA Draft Method 18, "Measurement of Gaseous Organic Compound Emissions by Gas Chromatography," Personal communication with Jeff Chappell, U.S. Environmental Protection Agency, IERL-RTP.

3. EPA Reference Method 3, "Gas Analysis for Carbon Dioxide, Oxygen, Excess Air, and Dry Molecular Weight," Appendix A to 40 CFR, Environmental Reporter, Bureau of National Affairs, Washington, D.C., December 5, 1980. pp. 33-36.

4. EPA Reference Method 4, "Determination of Moisture Content in Stack Gases," Appendix A to 40 CFR, Environmental Reporter, Bureau of National Affairs, Washington, D.C., December 5, 1980. pp. 36-41.

5. EPA Reference Method 1, "Sample and Velocity Traverses for Stationary Sources." Appendix A to 40 CFR, Environment Reporter. Bureau of National Affairs. Washington, D.C. December 5, 1980. pp. 23-25.

6. EPA Reference Method 2, "Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube), Appendix A to 40 CFR, Environmental Reporter, Bureau of National Affairs, Washington, D.C., December 5, 1980. pp. 25-33.

SECTION 6

RESULTS OF TESTING AND ANALYSIS

Catalytic incinerator performance data were collected on eight different incinerators at six industrial sites. These incinerators were applied in the can coating, coil coating, magnet wire and graphic arts printing industries.

Detailed discussions of the test results for each site are presented in the Site Test Reports, Volumes 2-8 of this report. The purpose of this section is to summarize and compare the results from all six sites. No attempt is made in this section to repeat all of the detailed discussions in the Site Test Reports. However, information considered necessary to provide an objective comparison of the performance of the eight incinerators is included.

Waste gas characteristics and incinerator operating conditions are discussed first. This information is then used as the basis for a comparative analysis of incinerator performance during typical plant and incinerator operation. A comparison of the effect of varying major operating parameters at each site is presented last.

6.1 WASTE GAS CHARACTERISTICS AND INCINERATOR OPERATING CONDITIONS

Waste gas characteristics and incinerator design and operating parameters for the eight incinerators are presented in Table 6-1. Each of the different characteristics and parameters shown in Table 6-1 are discussed in this section. Test methods used to obtain the different parameters are discussed in Section 5.0 and in the Site Test Reports.

TABLE 6-1. WASTE GAS CHARACTERISTICS AND INCINERATOR DESIGN AND OPERATING PARAMETERS

Plant ID (Incinerator No.)	Process Type	Waste Gas Flowrate[a] Nm^3/s (scfm)	Waste Gas Temperature °C (°F)	Major Solvents Identified[b]	Average Temperatures[c] Catalyst Inlet/Outlet °C	°F	Catalyst Bed Pressure Drop kPa ("H_2O)	Catalyst Type	Catalyst Age (months)	SLA Residence Time (sec)	Design Destruction Efficiency (%)
Plant C-1 (27)	Can Coating	3.6 (7600)[d]	121 (250)	toluene, xylenes, ethyl benzenes	363/396	(685/745)	0.60 (2.4)	Ceramic honeycomb	8	0.03	90
Plant C-1 (28)	Can Coating	3.2 (6780)[d]	89 (190)	MIBK, xylenes[e], methyl ethyl benzenes	316/410	(600/770)	0.57 (2.3)	Ceramic honeycomb	23/<1[f]	0.03	90
Plant C-4	Can Coating	2.52 (5330)	164 (327)	MIBK, cellosolve, xylenes, ethylbenzene[e]	332/393	(630/740)	0.42 (1.7)	Ceramic honeycomb	11[g]	0.03	90
Plant C-2	Graphic Arts Printing	0.9 (2000)	127 (260)	C12 to C18 hydrocarbons	493/438	(920/820)[h]	2.5 (10)	Ceramic honeycomb	1	NA	90
Plant C-3 (20)	Graphic Arts Printing	1.26 (2660)	177 (350)	C12 to C18 hydrocarbons	372/379	(701/713)	0.25 (1.0)	Ceramic spherical pellets	16	0.04[j]	90
Plant C-3 (21)	Graphic Arts Printing	2.21 (4670)	178 (352)	C12 to C18 hydrocarbons	353/412	(667/774)	0.25 (1.0)	Ceramic spherical pellets	8	0.04[k]	90
Plant C-5	Magnet Wire	0.28 (603)	233 (451)	phenol, cresols	393/507	(740/945)	0.17 (0.7)	Metal ribbons	<1	0.015[k]	NA[l]
Plant C-6	Coil Coating	5.33(11300)	143 (290)	MEK, toluene[e]	285/427	(545/800)	0.42 (1.7)	Ceramic honeycomb	1	0.03	95

FOOTNOTES FOR TABLE 6-1

[a]This is the total inlet gas flow to the incinerator on a wet basis.

[b]Solvents were identified by gas chromatography and/or mass spectroscopy.

[c]These temperatures represent the average temperatures measured for each incinerator during typical incinerator operation. Tests conducted at different operating temperatures are discussed in Section 6.3.

[d]These flowrates were calculated from a CO_2 mass balance around SLA fan (See Appendix A, Plant C-1 Site Test Report). Flows were not measured because no acceptable sampling location was available.

[e]Solvent formulations varied for different coatings. MIBK = methyl isobutyl ketone, MEK = methyl ethyl ketone.

[f]Two catalyst ages were tested at this plant.

[g]Catalyst was cleaned 5 months prior to test.

[h]This catalyst is believed to have been deactivated by either high temperature operation or material masking. The temperature drop across the catalyst bed and a 2.5 kPa ($10"H_2O$) pressure drop measured for this catalyst is evidence of the deactivation.

[i]The catalyst in the incinerator was 8 years old but the operating hours logged by the incinerator is much less than 8 years. The actual number of hours logged is, however, unknown.

[j]Assumes 40 percent void fraction.

[k]Assumes 50 percent void fraction.

[l]Design efficiency unknown because incinerator was modified by plant to increase catalyst volume.

Waste gas flowrates ranged widely for the eight incinerators from 0.28 to 5.33 Nm^3/s (600 to 11,300 scfm). The smallest flowrate was for the magnet wire plant while the largest was for the coil coating plant.

Comparison of waste gas temperatures shows a fairly narrow range from 89 to 177°C (190 to 350°F) for all plants except for the magnet wire plant. The magnet wire coater has a relatively high waste gas temperature because the curing oven in this process operates at a higher temperature.

The types of solvents destroyed in the catalytic incinerators varied considerably for the different industries. The inlet concentration of the solvents ranged from approximately 5 to 15 percent of the lower explosive limit (LEL). The can coating solvents generally consisted of aromatic compounds, such as toluene, xylenes and ethyl benzenes. Some of these coatings also contained methyl isobutyl ketone (MIBK) and/or cellosolve.

The inks used at the graphic arts printing plants contained a heavy organic solvent consisting of C_{12} through C_{18} hydrocarbons with an average molecular weight of about 210 g/mole.

The solvents in the magnet wire coatings were phenols and cresols and the coil coating solvents were methyl ethyl ketone (MEK) and toluene.

Average catalyst bed inlet and outlet temperatures were generally similar at the different plants except for Plants C-2 and C-5. At Plant C-2, the catalyst outlet temperature consistently averaged about 56°C (100°F) lower than the catalyst inlet temperature. This temperature drop suggests that no solvent destruction was occurring on the catalyst bed. These temperature readings were confirmed by multiple readings with several thermocouples and readout devices. The temperature drop across the catalyst bed, in conjunction with the very high catalyst bed pressure drop, is evidence that the Plant C-2 catalyst was fouled or deactivated and unable to

promote solvent oxidation.[1] The catalyst was probably damaged by either high temperature operation (7540°C, 1000°F) or material masking.

At the magnet wire plant, Plant C-5, the incinerator is typically operated at catalyst inlet and outlet temperatures higher than at the other plants. This higher operating temperature is necessary to avoid the possible condensation of coating resin on the catalyst bed. A small amount of the coating resin is carried out of the curing and drying oven with the waste gas.

Comparison of the catalyst types and residence times for the eight incinerators shows that the lowest SLA residence time is for the metal ribbon catalyst at Plant C-5. As discussed in Section 4.5, this incinerator was originally installed circa 1967 and was modified by the plant in 1974 to increase the catalyst volume. However, even with the increased catalyst volume, the incinerator still has a SLA residence time that is lower than the other more recently installed incinerators tested.

The age or service life of the catalyst beds tested ranged from several days to 23 months at all plants except C-2. At Plant C-2, the catalyst bed was 8 years old but initial plant information indicated that the incinerator had logged only 2000 hours of service since startup. This estimate was later found to be considerably in error but the actual service life of the catalyst is still unknown.

At Plants C-1 and C-5, the catalyst was replaced during the test period. The first catalyst tested at Plant C-5 was also of unknown age. Data for this catalyst is not presented in this report but is discussed in the Site Test Report for Plant C-5.

The design destruction efficiency for six of the eight incinerators is 90 percent and one incinerator has a 95 percent design efficiency. The design destruction efficiency for Plant C-5 is not available.

6.2 RESULTS OF COMPARATIVE ANALYSIS

A comparative analysis of performance for the eight catalytic incinerators is presented in this section. This analysis is based on the waste gas characteristics and incinerator operating conditions discussed in Section 6.1. The performance of the incinerators is compared in terms of solvent destruction efficiency, outlet gas solvent concentrations and energy usage.

Incinerator inlet and outlet concentrations presented in this section are based on EPA Method 25A analyses. The concentrations are reported as parts per million by volume carbon (ppmv) but were quantitated against propane standards. Destruction efficiencies presented in this section were calculated on the basis of inlet and outlet solvent mass flowrates except for Plant C-1. At Plant C-1, inlet and outlet gas flowrates could not be measured according to EPA Method 2 and these efficiencies were calculated directly from measured inlet and outlet Method 25A concentrations. Examples of the efficiency calculations are presented in Appendix A.

Method 25A concentrations, destruction efficiencies and energy usages for the eight catalytic incinerators are presented in Table 6-2. Two data sets are presented for incinerator 28 at Plant C-1. Each of the data sets for incinerator 28 represents a different catalyst age. The data in Table 6-2 were collected under steady state process and incinerator operating conditions.

6.2.1 Destruction Efficiency

As shown in Table 6-2, destruction efficiencies for the eight incinerators varied widely, from 80.1 to 98.6 percent. Major factors causing this variation include catalyst age or condition and SLA residence time.

TABLE 6-2. SUMMARY OF PERFORMANCE DATA FOR TYPICAL OPERATING CONDITIONS[a]

Plant ID (Incinerator No.)[b]	Type of Process	Coatings Testing	Hours of Data[c]	Method 25A Concentrations[d] Inlet (ppmv)	Outlet (ppmv)	Destruction Efficiency (%)[e]	Average Energy Usage[f] kJ/Nm³	(Btu/scf)	Heat Recovery
Plant C-1 (27)	Can Coating	1	27.6	4000-5810	181-275	95.4-96.4	270	(7.2)	39[j]
Plant C-1 (28)	Can Coating	3	7.8	2840-7760	173-321	93.4-95.9	230	(6.1)	46[j]
Plant C-1 (28)	Can Coating	7	26	2270-5755	46-341	96.3-98.6 (91.7-93.4)[g]	230	(6.1)	46[j]
Plant C-4	Can Coating	2	13	5480-7560	385-687	88.7/94.0	260	(6.9)	None
Plant C-2	Graphic Arts Printing	1	23	1020	169	81.2	780	(21)	None
Plant C-3 (20)	Graphic Arts Printing	1	5.5	1240	241	80.1	160	(4.3)[i]	36%[k]
Plant C-3 (21)	Graphic Arts Printing	5	7.2	1370-4030	90-165	93.4-95.9	80	(2.1)[i]	66%[k]
Plant C-5	Magnet Wire	1	13.8	8720	1590	80.6	240	(6.4)[i]	None
Plant C-6	Coil Coating	5	27	6220-12,860[h]	272-305	96.5-97.5	150	(3.9)	31%[j]

FOOTNOTES FOR TABLE 6-2

[a]Data presented in this table are for steady state incinerator and coating process operating conditions.

[b]Tests were conducted between November 1982 and March 1983.

[c]Represents hours of data collected at "typical" incinerator operating temperature (see Table 6-1). Data collected at other operating temperatures are discussed in Section 6.3.

[d]Concentrations are for the incinerator inlet/outlet gas streams. The range of values represents the range of average concentrations measured during monitoring periods for the different coatings tested. Monitoring period lengths generally exceeded 1 hour and ranged up to about 14 hours. Method 25A results for different monitoring periods are summarized in the Site Test Reports. ppmv = parts per million by volume carbon, quanitated against propane standards.

[e]For all plants except Plant C-1,
Destruction Efficiency = $\frac{Min - Mout}{Min} \times 100\%$, where

$$M = \text{VOC mass flowrate} = \frac{V \text{ moles C}}{10^6 \text{ moles gas}} \times \frac{12g \text{ C}}{\text{mole C}} \times \frac{\text{moles gas}}{0.024 \text{ m}^3} \times \frac{Q \text{ m}^3 \text{ gas}}{\text{sec}}$$

V = VOC concentration, ppmv (in or out)
Q = gas flowrate, Nm^3/sec (in or out)
For plant C-1, Destruction Efficiency = $\frac{Vin - Vout}{Vin} \times 100\%$.

[f]Energy usage is for fuel gas required to heat waste gas to catalyst inlet temperature.

[g]These values are for one of the 7 coatings tested. This solvent formulation apparently had a greater percentage of MIBK and a higher average solvent molecular weight than the other formulations tested.

[h]This concentration is for "main inlet" gas stream as shown in Figure 4-6.

[i]Energy usage calculated based on waste gas temperature and catalyst bed inlet temperature.

[j]Heat recovered by recycling incinerator outlet gas to drying oven. Represents percent recovery of heat generated by natural gas and fuel combustion in the incinerator.

[k]Heat recovered by recuperative heat exchange. Represents percent recovery of heat required to raise the waste gas temperature to the catalyst bed inlet temperature.

Of the eight incinerators, four achieved destruction efficiencies in excess of 90 percent on all of the coatings tested. Two of these incinerators achieved efficiencies in excess of 95 percent for all coatings. Three of the four incinerators showing efficiencies greater than 90 percent used ceramic-based honeycomb catalyst, with a 0.03 second residence time and one used ceramic-based spherical pellet catalyst, with a 0.04 second residence time. The catalyst ages in these incinerators ranged from new to 23 months.

The Plant C-4 incinerator showed destruction efficiencies of 88.4 and 94 percent, respectively for the two coatings tested. These efficiencies are slightly lower on average than those measured for the similarly designed incinerators at Plant C-1. As noted in Section 4.4, the catalyst in the Plant C-4 incinerator had become masked during the first 6 months of operation and was cleaned with an alkaline solution 5 months prior to testing. One possible explanation for the lower efficiencies measured at Plant C-4 compared to Plant C-1 is that the catalyst was still partially masked.

Destruction efficiencies of approximately 80 percent were observed for three of the eight incinerators: Plants C-2, C-3 (20) and C-5. The lower efficiencies for these systems can be attributed to either the catalyst condition or the catalyst bed residence time.

For Plant C-2, the comparatively low destruction efficiency of 81 percent is probably due to the catalyst being fouled. As discussed in Section 6.1, a temperature drop and a high pressure drop were measured for this catalyst. These conditions suggest that the catalyst was fouled or deactivated and unable to promote solvent oxidation[1]. The solvent destruction observed for the incinerator must have occurred in the burner zone of the incinerator instead of in the catalyst bed.

For Plant C-5, the comparatively low efficiency of 81 percent is most likely due to the shorter SLA residence time. The residence time for this incinerator was 0.015 seconds compared with 0.03 seconds or greater for the

incinerators showing destruction efficiencies in excess of 90 percent. As discussed in Section 6.1, the Plant C-5 incinerator was originally installed circa 1967 and was modified by the plant in 1974 to increase the catalyst volume. The current catalyst volume still provides only half the residence time of newly installed systems.

For Plant C-3, the only plausible explanation for the comparatively low efficiency is normal catalyst aging. No data are available that suggest any particular problems that may have resulted in deactivation of this catalyst. Comparison of incinerators 20 and 21 at Plant C-3 shows that the major difference between the incinerators is the service life or age of the catalysts, at 16 and 8 months, respectively.

The 16 month-old catalyst in incinerator 20 also shows a much lower destruction efficiency than the 23 month-old catalyst tested at Plant C-1 (28). This is somewhat unexpected because catalyst activity generally decreases with time. However, the catalyst geometries and solvent types differ for the two incinerators and the conditions effecting catalyst deactivation are not necessarily the same at both plants.

Comparison of the measured destruction efficiencies presented in Table 6-2 with the design efficiencies presented in Table 6-1 shows that two incinerators operated considerably below design levels. These were the Plant C-2 incinerator and incinerator 20 at Plant C-3. As discussed above, the lower efficiency at Plant C-2 was due to the catalyst being fouled and the lower efficiency for incinerator 20 was probably due to catalyst age.

A comparison of Method 25A and Method 18 THC destruction efficiencies is shown in Table 6-3. Data for different incinerator operating temperatures and different products are shown in Table 6-3 for Plants C-4, C-5, and C-6. The THC destruction efficiencies measured according to the two test methods are in good agreement.

TABLE 6-3. COMPARISON OF METHOD 25A AND METHOD 18 THC DESTRUCTION EFFICIENCIES

Plant ID	Product	Catalyst Temperature Inlet/Outlet °C	(°F)	Method 18 THC Destruction Efficiency	Method 25A Destruction Efficiency
C-4	A	318/382	(605/720)	95.6	94.0
C-4	B	335/397	(635/746)	89.4	88.7
C-4	B	368/432	(695/810)	92.3	91.0
C-4	B	391/452	(735/845)	93.6	92.4
C-5	A	402/482	(755/900)	78.9	79.5
C-5	A	468/554	(875/1030)	84.4	82.4
C-5	A	493/577	(920/1070)	83.3	82.0
C-6	A	285/443	(545/830)	96.3	97.5
C-6	B	341/443	(645/830)	96.6	97.0
C-6	D	288/374	(550/705)	94.3	95.9
C-6	E	277/435	(530/815)	96.1	97.3

6.2.2 Outlet Method 25A Concentrations

Outlet Method 25A concentrations measured for the eight incinerators varied fairly widely. As shown in Table 6-2, the lowest concentration of 46 ppmv was for Plant C-1, incinerator 28 and the highest, 1600 ppmv, was for Plant C-5.

All of the incinerators showed outlet concentrations less than 700 ppmv except for Plant C-5.

6.2.3 Energy Usage

Average energy usage for the eight incinerators in terms of energy per unit volume of waste gas varied over a fairly narrow range except for Plant C-2. For plants other than C-2, energy usage ranged from 78 to 270 kJ/m^3 (2.1 to 7.2 Btu/scf). At Plant C-2, the catalyst bed inlet temperature was 110 to 170°C (200 to 300°F) higher than at the other plants and energy usage was estimated to be 780 kJ/m^3 (21 Btu/scf).

Five of the eight incinerators employed some type of heat recovery. At Plants C-1 and C-6, outlet gas from the incinerator was recycled to the drying oven and at Plant C-3 recuperative heat exchangers were used.

For the plants using gas recycle, heat recovery rates ranged from 31 to 46 percent. This heat recovery represents the percentage of heat generated by natural gas and solvent combustion that is reused in the process (see Appendix B).

At Plant C-3, heat recovery was determined to be 36 and 66 percent for incinerators 20 and 21, respectively. This heat recovery represents the percent recovery of heat required to raise the waste gas temperature to the catalyst bed inlet temperature.

6.3 EFFECT OF VARYING OPERATING PARAMETERS

Parametric analyses were performed on the Method 25A results for each incinerator to assess the effect of operating parameter variations on performance. Incinerator operating temperature and inlet solvent concentrations were found to be important parameters. The effect of these parameters on incinerator performance is discussed in detail in the Site Test Reports and is compared for the different incinerators in this section.

The Method 18 results for each incinerator were analyzed in an attempt to determine the effect of solvent type on performance. These results appear to show weak trends in the relative destruction efficiencies of different solvents. However, few conclusions could be drawn from these results because of large statistical variability in the data. Confidence intervals for the average destruction efficiencies measured for different solvents overlap because the number of samples taken is statistically small and the standard deviation of the measured concentrations is large. Analyses of the Method 18 data for each plant are included in the Site Test Reports but are not repeated in this section.

Data presented in this section were taken directly from the Site Test Reports except where otherwise noted. No data are presented in this section for Plant C-2 because operating conditions were not varied at this plant. Similarly, Plant C-1 data are not included in the temperature analysis because the operating temperature was not varied.

Catalyst Operating Temperature

At Plants C-3 through C-6, the incinerator operating temperature was varied intentionally to observe the effect on incinerator performance. For purpose of this analysis, the catalyst inlet temperature was taken to represent the catalyst operating temperature. The effect of catalyst inlet temperature on VOC destruction efficiency for the five incinerators tested

at Plants C-3 through C-6 is illustrated in Figure 6-1. Figure 6-2 shows the effect of catalyst inlet temperature on outlet THC concentration of the five incinerators. All of the data presented in Figures 6-1 and 6-2 represent steady-state monitoring periods at a relatively constant inlet THC concentration for each of the incinerators tested.

As shown in Figure 6-1, increasing the catalyst operating temperature resulted in increased destruction efficiency. For two of the five incinerators, the effect of catalyst temperature on destruction efficiency was relatively small. The incinerators at Plants C-3 and C-5 showed a fairly large effect of temperature on efficiency while Plants C-4 and C-6 showed a relatively small effect. The greatest effect of temperature was observed for incinerator 20 at Plant C-3, where a 25°F increase in catalyst inlet temperature resulted in a 2.5 percent increase in destruction efficiency.

Figure 6-2 demonstrates that, as expected, increasing the catalyst operating temperature resulted in decreased outlet Method 25A concentrations for the five incinerators shown. As with destruction efficiency, the outlet Method 25A concentrations were most greatly affected by changes in catalyst operating temperature at Plants C-3 and C-4. The effect of catalyst operating temperature on outlet Method 25A concentration was smaller at Plants C-5 and C-6.

Inlet Method 25A Concentration

The THC concentration of the inlet SLA varied during testing at each of the incinerators due to changes in product type, product size, solvents used, and line speeds. The effect of variations in inlet Method 25A concentration is shown in Figure 6-3 for seven incinerators. Inlet concentrations shown in Figure 6-3 for Plant C-6 were calculated from inlet THC mass flowrates presented in the Interim Test Report for this plant. An example of the calculation is shown in Appendix C.

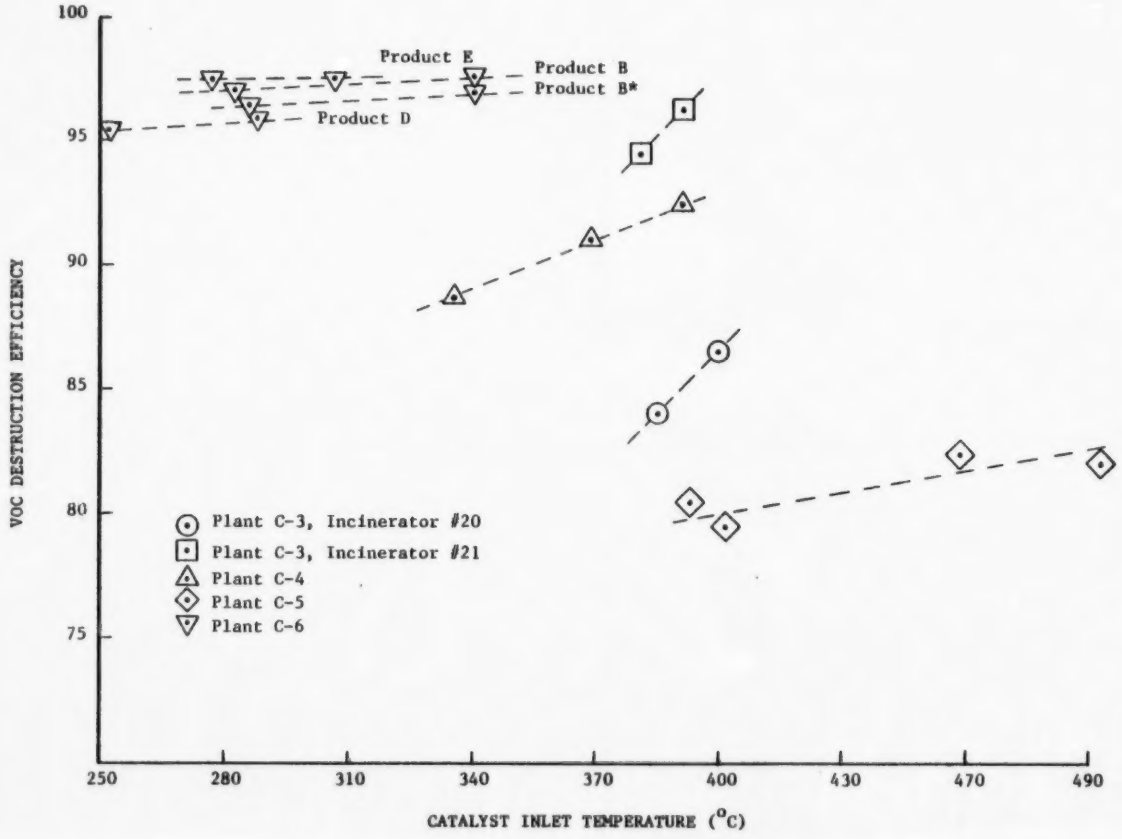

Figure 6-1. Effect of catalyst inlet temperature on destruction efficiency.

*Data is presented for two different inlet concentrations of Product B.

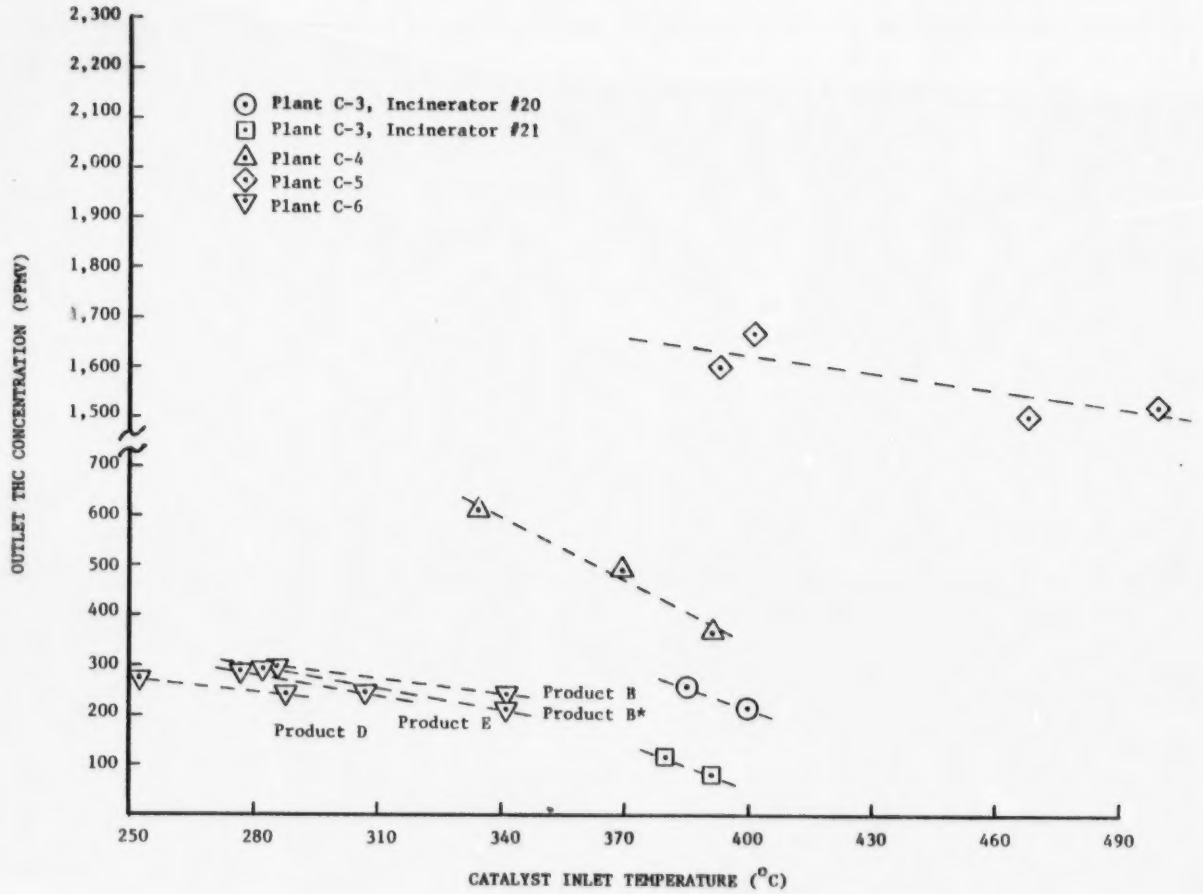

Figure 6-2. Effect of catalyst inlet temperature on outlet Method 25A concentration.

*Data is presented for two different inlet concentrations of Product B.

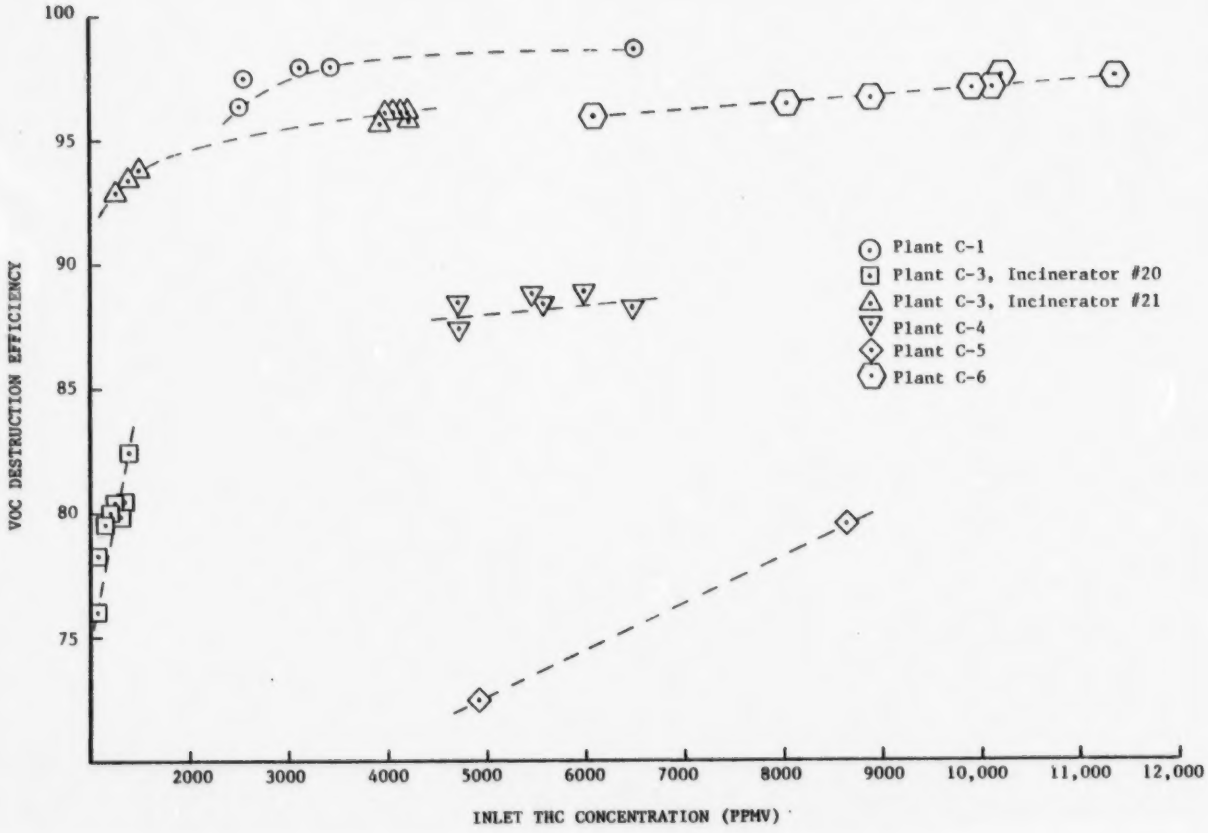

Figure 6-3. Effect of inlet Method 25A concentration on destruction efficiency.

*For Plant C-6, inlet THC mass flowrates presented in the interim test report were converted to "equivalent" concentration (see Appendix C) for preparation of this figure.

As shown in Figure 6-3, destruction efficiency increased in all cases with increased inlet Method 25A concentration. The effect of increased inlet Method 25A concentration appeared to be greatest at lower destruction efficiencies. A change in inlet Method 25A concentration had the greatest effect on destruction efficiency for incinerator 20 at Plant C-3 and the incinerator at Plant C-5. Both of these incinerators operated at destruction efficiencies less than 85 percent. The effect of inlet Method 25A concentration on destruction efficiency appears to be smaller for the remaining incinerators, all of which showed higher destruction efficiencies.

SECTION 6 REFERENCES

1. Telecon. E. Smith, Johnson Matthey, Inc., with J. R. Blacksmith, Radian Corporation. Conversation about Plant C-2 incinerator. February 8, 1983.

SECTION 7

RECOMMENDATIONS

The EPA catalytic incinerator program was initiated to assemble analyze, assess and develop information on the use and the ability to use catalytic incinerators for VOC control. The program concentrated on the use of the technology for control of VOC process emissions. Section 1 details the two primary objectives for the total program and states (objective 2) the objective of the current testing program: to gather actual performance data on operating industrial catalytic incinerators. The objective of the testing program has been successfully met for four major industrial users of catalytic incinerators including: can coating, coil coating, web off-set printing and magnet wire coating.

Work from several catalytic incinerator projects has vastly increased the information base from which both EPA and industrial users can draw useful conclusions. However, there are still data gaps and information deficiencies that when filled, will make the total technology assessment of catalytic incineration more complete. Recommendations for future work in catalytic incineration will compromise the remainder of this section.

Future work in the area of catalytic incineration should be focussed on providing potential industry users and the EPA with additional information needed to assess the applicability and potential performance of incinerators applied in industries other than those tested in this program. Information that will be required to meet this objective includes (1) a better understanding of the effect of solvent type on catalytic incinerator performance and (2) performance data on solvent types significantly different than those tested in this program.

Further data on the effect of solvent type on incinerator performance should be collected. This data will allow the prediction of potential destruction efficiencies achievable on processes using similar or more easily destroyed solvents than those tested. This data should include actual destruction data but should also consider the chemical/physical makeup of the solvents. In this way general trends might be established between the solvents for which there is destruction data and for solvents for which there is no data, but there is chemical/physical similarity. This type of information would be very useful in a predictive way for anyone desiring to estimate the destruction efficiency for a given solvent.

SECTION 7 REFERENCES

1. U.S. Environmental Protection Agency. Control of Volatile Organic Emissions from Existing Sources. Volume 8: Graphic Arts - Rotogravure and Flexography. Office of Air Quality Planning and Standards Pb No. EPA-450/2-78-033. December 1977.

APPENDIX A

EXAMPLE CALCULATIONS

Methods used to calculate destruction efficiency and heat recovery are presented in the following subsections.

A.1 DESTRUCTION EFFICIENCY

For all plants except Plant C-1, the destruction efficiency is based on inlet and outlet THC mass rates as follows:

$$DE = \frac{Min - Mout}{Min} \times 100\%$$

where DE = destruction efficiency, %

Min = inlet THC mass rate, g C/sec

Mout = outlet THC mass rate, g C/sec

THC mass rates are based on measured Method 25A concentrations and gas flowrates:

$$M = \frac{(V)\ \text{moles C}}{10^6\ \text{moles gas}} \times \frac{12\text{gC}}{\text{mole C}} \times \frac{\text{mole gas}}{0.024\ \text{m}^3\ \text{gas}} \times \frac{(Q)\ \text{m}^3\ \text{gas}}{\text{sec}}$$

where M = THC mass rate (inlet or outlet) g C/sec

V = THC concentration (inlet or outlet), ppmv

Q = gas flowrate (inlet or outlet), Nm^3/sec

Standard or normal conditions refer to one atmosphere of pressure and 20°C (68°F).

For Plant C-1, inlet and outlet gas flowrates could not be measured because no acceptable location was available. Destruction efficiency for this plant was based on Method 25A inlet and outlet concentrations as follows:

$$DE = \frac{Vin - Vout}{Vin}$$

where V = THC concentration (inlet or outlet), ppmv

A.2 HEAT RECOVERY BY RECUPERATIVE HEAT EXCHANGE

For recuperative exchangers, the heat recovery is defined as the percentage of heat provided by the heat recovery system of the total required to raise the inlet solvent laden air (SLA) temperature to the catalyst inlet temperature:

$$HR = \frac{HEX}{Q_{TOTAL}} \times 100\%$$

where H = heat recovery, %

Q_{HER} = heat added to the inlet SLA by heat exchange with the incinerator exhaust gas, J/sec

Q_{TOTAL} = heat necessary to raise the inlet SLA temperature to the catalyst inlet temperature, J/sec

The above equation is solved by making the following assumptions and substitutions:

$$HR = \frac{mCp\ T_{SLA,HEXout} - T_{SLA,HEXin}}{mCp\ T_{SLA,catin} - T_{SLA,HEXin}} \times 100\%$$

where m = mass flowrate of SLA, gmole/sec

Cp = specific heat of SLA at the elevated temperatures, J/gmole°K

$T_{SLA,HEXout}$ = temperature of the SLA exiting the heat exchanger, °K

$T_{SLA,HEXin}$ = temperatures of the SLA entering the heat exchanger, °K

$T_{SLA,catin}$ = temperature of the SLA entering the catalyst bed, °K

Of the above temperatures, $T_{SLA,HEXout}$ was not measured. It was calculated by performing an energy balance around the heat exchanger:

$$mCp\ (T_{SLA,HEXout} - T_{SLA,HEXin}) = mCp\ (T_{exh,HEXin} - T_{exh,HEXout})$$

where $T_{exh,HEXin}$ = temperature of the exhaust gas entering the heat exchanger, °K

$T_{exh,HEXout}$ = temperature of the exhaust gas exiting the heat exchanger, °K

The SLA and exhaust gas mass rates are assumed to be equal for this calculation, since the contribution by the fuel gas to the exhaust gas mass rate is negligible. Specific heats of the inlet and outlet streams are also assumed to be equal over the measured temperature range.

A.3 HEAT RECOVERY BY EXHAUST GAS RECYCLE

For systems with outlet gas recycle, heat recovery was defined as the percent of heat generated by natural gas and solvent combustion that is reused in the process. The heat reused in the process was assumed to be equivalent to all heat not exiting the process with the stack exhaust gas. Heat recovery was then calculated as follows:

$$HR = \left[1 - \frac{Q_{ex}}{Q_{gen}}\right] \times 100\%$$

where HR = heat recovery, %

Q_{ex} = heat added to stack exhaust gas by natural gas

and solvent combustion, J/sec

Q_{gen} = total heat generated by natural gas and solvent combustion, J/sec

The above equation is solved by making the following assumptions and and substitutions:

$$HR = [1 - \frac{m_{stack}\ Cp(T_{stack} - T_{sys\ in})}{m_{SLA}\ Cp(T_{catout} - T_{SLA\ in})}] \times 100\%$$

where m = gas mass flowrate (stack gas or SLA), g mole/sec

Cp = average specific heat of SLA for the range of temperature, J/g mole °K

T_{stack} = temperature of the stack exhaust gas, °K

$T_{sys\ in}$ = temperature of system in leakage air entering the ends of the drying oven, °K

T_{catout} = temperature of SLA exiting the catalyst bed, °K

$T_{SLA\ in}$ = temperature of SLA entering the incinerator, °K

The temperature of the in leakage air is equal to the ambient temperature of the coating room near the oven or approximately 32°C (90°F).

APPENDIX B

SUMMARIES OF METHOD 25A RESULTS

The results of Method 25A analyses for the eight incinerators tested at Plants C-1 through C-6 are presented in Tables B-1 through B-8. Results presented in the tables represent all data collected under normal process operation at each of the plants. Periods during which process operation was unsteady are noted. Different solvents used during testing at each incinerator are identified by letter.

TABLE B-1. SUMMARY OF METHOD 25A RESULTS FOR INCINERATOR 27 - PLANT C-1

Date	Monitoring Period	Length of Monitoring Period (minutes)	Product ID	Solvents Added To Coating[c]	Inlet Method 25A Concentrations (ppmv)[a]	Outlet Method 25A Concentration (ppmv)[a]	Average Destruction Efficiency (%)[b]	Average Gas Temperature °C (°F) Catalyst Inlet	Catalyst Outlet	Outlet CO (ppmv)
11/16/82	13:03-14:04	62	F	mineral spirits	1366[d]	e	NA	393 (730)	393 (740)	-
11/16/82	14:05-16:55	171	F	mineral spirits	1767	e	NA	393 (730)	393 (740)	-
11/16/82 - 11/17/82	20:44-03:22	399	F	mineral spirits	2220	e	NA	374 (705)	407 (765)	-
11/17/82	05:14-09:07	234	G	50% mineral spirits 30% isophorone 20% DIBK	3356	e	NA	374 (705)	404 (760)	-
11/19/82	20:04-20:21	18	K	butyl cellosolve	1796[d]	197	89.0[d]	388 (730)	393 (740)	-
11/19/82- 11/20/82	22:35-05:52	438	K	butyl cellosolve	4069	181	95.6	357 (675)	396 (745)	-
11/22/82	07:12-08:23	72	K	butyl cellosolve	2158[f]	235	89.1[f]	354 (670)	399 (750)	-
11/22/82	09:32-11:31	120	F	butyl cellosolve	5827	212	96.4	338 (640)	399 (750)	13
11/22/82	12:22-19:48	447	K	butyl cellosolve	4460	205	95.4	343 (650)	393 (740)	-
11/22/82 - 11/23/82	20:50-06:01	552	K	butyl cellosolve	4964	225	95.5	343 (650)	393 (740)	-
11/23/82	06:09-07:42	96	K	butyl cellosolve	5582	275	95.1	341 (645)	393 (740)	10

[a] ppmv = parts per million as C_1, quantitated against propane.

[b] Destruction Efficiency = $\frac{Vin - Vout}{Vin}$ X 100% where, V= THC concentration (in or out), ppmv.

[c] These solvents are added in small amounts to pre-mixed coatings purchased by Plant C-1. DIBK = diisobutyl ketone, MIBK = methylisobutyl keytone.

[d] Process problems - unsteady operation.

[e] These data have been invalidated due to a suspected leak in the sample acquisition system. THC values measured on the Byron 401 were less than the inlet gas CH4 concentrations.

[f] These data were collected during process startup.

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TABLE B-2. SUMMARY OF METHOD 25A SAMPLING RESULTS FOR INCINERATOR 28 - PLANT C-1

Date	Monitoring Period	Length of Monitoring Period (minutes)	Product ID	Solvents Added To Coating[b]	Inlet Method 25A Concentrations (ppmv)[a]	Outlet Method 25A Concentration (ppmv)[a]	Average Destruction Efficiency (%)[b]	Average Gas Temperature °C (°F) Catalyst Inlet	Catalyst Outlet	Outlet CO (ppmv)
11/12/82	20:03-21:09	24[d]	A	butyl cellosolve	4055[e]	201	93.0	282 (540)	402 (755)	-
11/12/82 - 11/13/82	22:31-02:33	243	B	50% mineral spirits 50% butyl cellosolve	2848	173	93.9	313 (595)	399 (750)	-
11/13/82	03:22-06:42	201	C	80% mineral spirits 20% isophorone	7809	321	95.9	296 (565)	457 (855)	-
11/15/82	21:10-21:42	33	D	mineral spirits	2400	89	96.3	346 (655)	396 (745)	-
11/15/82	22:58-23:18	21	D	mineral spirits	685[f]	51	92.6[f]	332 (630)	404 (760)	-
11/16/82	00:48-02:05	78	D	mineral spirits	777[f]	44	94.3[f]	327 (620)	399 (750)	-
11/16/82	02:06-03:35	90	D	mineral spirits	2603	95	96.6	329 (625)	396 (745)	-
11/16/82	04:39-06:57	141	E	mineral spirits	2293	65	97.2	332 (630)	396 (745)	-
11/19/82	00:57-03:50	174	I	DIBK[c]	2317	58	97.5	344 (651)	399 (750)	-
11/19/82	04:21-08:08	228	J	mineral spirits	2203	68	97.8	324 (615)	399 (750)	-
11/19/82	09:24-10:59	96	J	mineral spirits	3033	68	97.8	321 (610)	398 (750)	3
11/19/82	11:31-12:30	60	J	mineral spirits	1698[g]	38	97.7[d]	349 (660)	396 (745)	1
11/19/82	14:22-15:24	63	A	butyl cellosolve	2284	84	98.5	308 (585)	407 (760)	-
11/19/82	15:51-16:38	48	A	butyl cellosolve	3409	46	98.7	349 (660)	402 (755)	-
11/23/82	18:24-20:01	98	L	MIBK[c]	4142[g]	341	91.8	266 (510)	452 (845)	-
11/23/82	20:22-23:18	177	L	MIBK	2972[g]	186	93.7	279 (535)	438 (820)	-
11/24/82	00:47-07:35	409	L	MIBK	4124[g]	274	93.4	285 (545)	429 (805)	-

[a] ppmv = parts per million as C_1, quantitated against propane. NMHC = non-methane hydrocarbons, THC = total hydrocarbons.

[b] Destruction Efficiency = $\frac{Vin - Vout}{Vin} \times 100\%$ where, V= THC concentration (in or out), ppmv

[c] These solvents are added in small amounts to pre-mixed coatings purchased by Plant C-1. DIBK = diisobutyl ketone, MIBK = methyl-isobutyl keytone.

[d] Extended process down time not included in this period.

[e] Three of eight inlet data points for this period exceeded full-scale value of 5145 ppmv.

[f] Process problems - unsteady operation.

[g] Several inlet data points exceeded full-scale value of 12140 ppmv during this period.

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TABLE B-3. SUMMARY OF EPA METHOD 25A SAMPLING RESULTS - PLANT C-2

Press Status	Incinerator Status	Average Inlet THC Concentration, ppmc	Average Outlet THC Concentration, ppmc	Average Inlet THC Mass Rate(M_i), kgC/hr[a] (lbC/hr)	Average Outlet THC Mass Rate(M_o), kgC/hr[a] (lbC/hr)	THC Destruction Efficiency (DE), %[b]
On	On	1020	169	1.70 (3.74)	0.319 (0.702)	81.2
Off	On	187	135	0.312 (0.687)	0.255 (0.561)	18.3
Weighted Average[c]		714	157	1.19 (2.62)	0.295 (0.650)	75.2

[a] $M = \left(\frac{(C) \text{ mole C}}{\text{mole gas}}\right)\left(\frac{12 \text{ lb C}}{\text{mole C}}\right)\left(\frac{\text{mole gas}}{378 \text{ ft}^3}\right)\left(\frac{(Q) \text{ ft}^3}{\text{min}}\right)\left(\frac{60 \text{ min}}{\text{hr}}\right)\left(\frac{0.454 \text{ kg}}{\text{lb}}\right)$, where C = THC concentration, ppmc
Q = gas flow rate, scfm (wet).

[b] $DE = \frac{M_i - M_o}{M_i} \times 100\%$.

[c] Press on 63.3% of time; press off 36.7% of time.

TABLE B-4. SUMMARIZED EPA METHOD 25A RESULTS FOR INCINERATOR 20 - PLANT C-3

Test Number	Catalyst Temperature Setpoint, °C (°F)	Operating Conditions/Hours[a]	Product ID	Web Speed, m/sec (fpm)	Inlet THC Concentration (C_i), ppmc	Outlet THC Concentration (C_o), ppmc	Catalyst ΔT, °C (°F)	Destruction[c] Efficiency, %
1	371 (700)	Steady-state/5.5	A	6.65 (1310)	1240	241	7 (12)	80.1
		Unsteady-state/4.1		-[b]	280	98	-	65.0
		Total/9.6		-	830	180	-	78.3
2	385 (725)	Steady-state/6.7	A	6.60 (1300)	1530	248	9 (16)	83.8
		Unsteady-state/1.7		-	168	30	-	82.1
		Total/8.4		-	1250	204	-	83.7
3	399 (750)	Steady-state/3.0	A	7.11 (1400)	1690	227	10 (18)	86.6
		Unsteady-state/1.6		-	177	95	-	46.3
		Total/4.6		-	1160	181	-	84.4

[a] Does not include time periods in which (1) instruments were undergoing calibration, (2) the incinerator was shut down, or (3) instrument malfunctions invalidated the data.

[b] Value is highly variable and, therefore, not calculated or monitored.

[c] Destruction Efficiency = $\frac{M_{in} - M_{out}}{M_{in}} \times 100\%$, where

M = THC mass rate = $\frac{(V) \text{ moles C}}{10^6 \text{ moles gas}} \times \frac{12 \text{ gC}}{\text{mole C}} \times \frac{\text{mole gas}}{0.0237 \text{ m}^3\text{gas}} \times \frac{(Q) \text{ m}^3\text{gas}}{\text{sec}}$

V = THC concentration, ppmc (in or out)

Q = gas flow rate, Nm^3/sec (in or out)

TABLE B-5. SUMMARIZED EPA METHOD 25A RESULTS FOR INCINERATOR 21 - PLANT C-3

Test Number	Catalyst Temperature Setpoint, °C (°F)	Operating Conditions/Hours[a]	Product ID	Web Speed, m/sec (fpm)	Inlet THC Concentration (C_i), ppmc	Outlet THC Concentration (C_o), ppmc	Catalyst ΔT, °C (°F)	Destruction[c] Efficiency, %
1	371 (700)	Steady-state/5.5	B	5.74 (1130)[b]	4030	165	63 (114)	95.9
		Unsteady-state/3.0		-	807	55	-	93.2
		Total/8.5		-	2900	126	-	95.7
		Steady-state/1.7	C	5.59 (1100)	1370	90	22 (40)	93.4
		Unsteady-state/0.9		-	296	32	-	89.2
		Total/2.6		-	983	70	-	92.9
2	385 (725)	Steady-state/4.9	C	5.33 (1050)	1670	92	29 (53)	94.5
		Unsteady-state/0.9		-	136	27	-	80.0
		Total/5.8		-	1440	82	-	94.3
		Steady-state/5.4	D	6.10 (1200)	1910	100	28 (50)	94.7
		Unsteady-state/0.7		-	604	74	-	87.7
		Total/6.1		-	1760	94	-	94.6
3	399 (750)	Steady-state/4.4	E	5.94 (1170)	2910	115	42 (75)	96.0
		Unsteady-state/1.0		-	729	29	-	96.0
		Total/5.4		-	2500	99	-	96.0
		Steady-state/1.9	F	4.17 (820)	2070	84	39 (71)	95.9
		Unsteady-state/7.3		-	933	44	-	95.3
		Total/9.2		-	1170	52	-	95.6

[a] Does not include time periods in which (1) instruments were undergoing calibration and (2) the incinerator was shut down.

[b] Value is highly variable and, therefore, not calculated or monitored.

[c] Destruction Efficiency = $\frac{M_{in} - M_{out}}{M_{in}} \times 100\%$, where

M = THC mass rate = $\frac{(V) \text{ moles C}}{10^6 \text{ moles gas}} \times \frac{12 \text{ gC}}{\text{mole C}} \times \frac{\text{mole gas}}{0.0237 \text{ m}^3 \text{gas}} \times \frac{(Q) \text{ m}^3 \text{ gas}}{\text{sec}}$

V = THC concentration, ppmc (in or out)

Q = gas flow rate, Nm^3/sec (in or out)

TABLE B-6. SUMMARY OF METHOD 25A SAMPLING RESULTS - PLANT C-4

Date	Monitoring Period	Length of Monitoring Period (min)	Product ID	Average Gas Temperature °C (°F)		Inlet THC Concentration (ppmv-C)[a]	Outlet THC Concentration (ppmv-C)[a]	Average Destruction Efficiency[d]
				Catalyst Inlet	Catalyst Outlet			
1/31/83	2139 - 2252	73	A	318 (605)	382 (720)	7,562	408	94.0
2/1/83	0727 - 0809	45	A	318 (605)	366 (690)	6,822[b]	385	93.8[b]
2/1/83	1929 - 2101	94	A	335 (635)	363 (685)	2,545[c]	251	88.8[c]
2/3/83	1300 - 1911	323	B	335 (635)	396 (745)	5,998	601	88.9
2/3/83	2051 - 2301	130	B	335 (635)	385 (725)	5,484	564	88.7
2/4/83	1017 - 1117	61	B	332 (630)	385 (725)	4,725	546	87.3
2/4/83	1210 - 1222	12	B	335 (635)	354 (670)	4,198	530	86.1
2/4/83	1440 - 1710	152	B	368 (695)	432 (810)	6,060	495	91.0
2/4/83	1824 - 2043	142	B	363 (685)	443 (830)	6,546[b]	531	91.0[b]
2/4/83	2044 - 2213	90	B	377 (710)	454 (850)	6,403[b]	445	92.3[b]
2/4/83	2217 - 2242	25	B	393 (740)	460 (860)	6,435[b]	440	92.4[b]
2/4/83 - 2/5/83	2259 - 0101	123	B	391 (735)	452 (845)	5,275	363	92.4
2/5/83	0102 - 0158	57	B	371 (700)	432 (810)	5,526[b]	500	90.0[b]
2/5/83	0159 - 0310	71	B	335 (635)	402 (755)	5,618	592	88.4
2/5/83	0319 - 0534	138	B	335 (635)	407 (765)	6,418	687	88.2
2/5/83	0608 - 1113	264	B	332 (630)	388 (730)	4,714	501	88.3

[a] ppmv-C = parts per million by volume as carbon quanitated against propane.

[b] Unsteady catalyst inlet temperature.

[c] Unsteady process operation.

[d] Destruction Efficiency = $\frac{Min - Mout}{Min} \times 100\%$, where

$$M = \text{THC Mass Rate} = \frac{(V) \text{ moles C}}{10^6 \text{ moles gas}} \times \frac{12 gC}{\text{mole C}} \times \frac{\text{mole gas}}{0.024 m^3 \text{ gas}} \times \frac{(Q)\ m^3 \text{ gas}}{\text{sec}}$$

V = THC concentration (inlet or outlet), ppmv

Q = gas glowrate (inlet or outlet), Nm^3/sec

TABLE B-7. SUMMARY OF METHOD 25A SAMPLING RESULTS - PLANT C-5

Date	Monitoring Period	Minutes of Data Collected	Inlet THC Concentration ppmv-C	Outlet THC Concentration ppmv-C	Destruction Efficiency (%)	Catalyst Inlet Temperature °C (°F)	Catalyst Outlet Temperature °C (°F)
2/15/83	18:17-20:01	105	8954	1876	77.8[a]	396 (745)	485 (905)
2/15-2/16/83	20:07-03:57	470	8908	2194	73.9	407 (765)	499 (930)
2/16/83	03:58-06:04	127	NA	2452	NA	407 (765)	499 (930)
	06:06-08:03	118	NA	2651	NA	402 (755)	488 (910)
	08:04-10:19	118	8710	2422	70.5	410 (770)	502 (935)
	16:48-19:29	162	8535	1404	82.5[b]	379 (715)	499 (930)
2/16-2/17/83	19:31-09:17	826	8720	1591	80.6	393 (740)	507 (945)
2/17/83	09:24-11:23	120	8299	1666	78.7	399 (750)	513 (955)
	11:28-12:30	63	8616	1716	78.9[a]	457 (855)	554(1030)
2/17-2/18/83	18:08-08:40	841	9021	1529	82.0	493 (920)	577(1070)
2/18/83	08:43-10:17	93	8825	1459	82.5[a]	488 (910)	568(1055)
	12:44-14:46	123	8862	1374	83.5	468 (875)	554(1030)
	17:04-21:15	247	9175	1564	81.1[a]	468 (875)	549(1020)
	21:16-22:12	57	8637	1541	81.1	418 (785)	502 (935)
2/18-2/19/83	22:13-00:09	117	8645	1669	79.5	402 (755)	482 (900)
2/19/83	00:10-00:40	31	8841	1916[c]	77.0	399 (750)	479 (895)
	00:41-02:15	95	4638	1526	65.1[d]	413 (775)	457 (855)
	02:16-05:18	183	5047	1155	75.7[d]	418 (785)	454 (850)
	05:19-08:49	204	8480	1605	79.9[e]	399 (750)	477 (890)

NA = Data not available.

[a]Temperature unsteady during a portion of the monitoring period - typically this was 50-100% of monitoring time.

[b]Data collected during period immediately following catalyst changeout. Catalyst not at steady state.

[c]Outlet concentration increased during this period from 1700-2000 ppm. Suspected cause of increase is process upset just prior to shutdown of ½ of coater.

[d]Only half of wire coater operating during this period.

[e]Process not back to steady state after half of coater was down.

TABLE B-8. SUMMARY OF EPA METHOD 25A SAMPLING RESULTS - PLANT C-6

Date	Monitoring Period	Length of Monitoring Period	Product ID	Main Inlet THC Concentration[a] (ppmv)	Floor Sweep THC Concentration[a] (ppmv)	Outlet THC Concentration[a] (ppmv)	THC Mass Flowrates Inlet kg/hr (lb/hr)	THC Mass Flowrates Outlet kg/hr (lb/hr)	Destruction Efficiency[k] (%)	Catalyst Inlet Temperature °C (°F)	Catalyst Outlet Temperature °C (°F)
2/25/83	17:02-18:06[b]	65	F	8006	--	201	71.2 (157)	2.0 (4.3)	97.3	285 (545)	393 (740)
2/25/83	20:53-21:34[b]	42	F	8811	--	199	78.0 (172)	1.9 (4.2)	97.6	285 (545)	396 (745)
2/28/83	07:25-08:11	47	B	11125	--	263	98.0 (216)	2.5 (5.6)	97.4	285 (545)	416 (780)
2/28/83	14:06-15:06	66	B	10947	--	291	96.2 (212)	2.8 (6.2)	97.1	285 (545)	427 (800)
2/28/83	15:39-17:37	118	B	10830	2382[c]	294	94.8 (209)	2.8 (6.2)	97.0	282 (540)	416 (780)
2/28/83	18:13-19:40	87	B	10926	2596[d]	305	96.2 (212)	3.0 (6.5)	97.0	277 (530)	418 (785)
2/28/83	19:47-20:57	72	B	10970	--	290	96.6 (213)	2.8 (6.2)	97.1	277 (530)	418 (785)
2/28/83	21:47-22:04	18	B	10217	--	291	90.3 (199)	2.8 (6.2)	96.9	277 (530)	418 (785)
3/1/83	13:58-15:00	63	A	11514	--	287	101 (223)	2.8 (6.1)	97.3	274 (525)	421 (790)
3/1/83	17:11-18:24	74	A	12864[e]	--	295	112 (248)	2.9 (6.3)	97.5	285 (545)	443 (830)
3/1/83	19:56-20:59	64	A	12504[e]	2592[f]	286	109 (241)	2.8 (6.1)	97.5	282 (540)	435 (815)
3/1/83	22:06-23:36	91	A	12303	--	289	108 (238)	2.8 (6.2)	97.4	285 (545)	438 (820)
3/2/83	00:31-02:30	93	A	12505	--	293	109 (241)	2.8 (6.2)	97.4	285 (545)	446 (835)
3/2/83	04:38-06:38	123	B	10183	--	280	89.8 (198)	2.7 (5.9)	97.0	282 (540)	421 (790)
3/2/83	07:13-08:50	100	B	11200	--	293	98.4 (217)	2.8 (6.2)	97.1	282 (540)	438 (820)
3/2/83	09:33-11:14	102	B	12358	--	250	108 (239)	2.4 (5.3)	97.8	338 (640)	474 (885)
3/2/83	12:32-14:02	91	B	10122	--	218	89.4 (197)	2.1 (4.7)	97.6	341 (645)	457 (855)
3/2/83	19:37-21:21	64[g]	C	8806	--	286	78.0 (172)	2.8 (6.1)	96.5	274 (525)	424 (795)
3/3/83	09:32-11:04	93	D	6485	--	269	58.1 (128)	2.6 (5.7)	95.5	252 (485)	335 (635)
3/3/83	11:44-12:15	32	D	6222	--	272	55.8 (123)	2.6 (5.8)	95.3	254 (490)	341 (645)
3/3/83	15:56-17:11	76	D	6542	2452[h]	248	58.5 (129)	2.4 (5.3)	95.9	288 (550)	374 (705)
3/3/83	20:15-00:03	217	B	8794	2888[i]	245	78.0 (172)	2.4 (5.3)	97.0	341 (645)	443 (830)
3/4/83	00:51-01:57	67	B	9594	--	298	84.8 (187)	2.9 (6.3)	96.6	279 (535)	407 (765)
3/4/83	02:43-05:06	144	B	9467	--	299	83.9 (185)	2.9 (6.4)	96.5	285 (545)	407 (765)
3/4/83	05:40-07:55	136	B	9212	--	295	81.7 (180)	2.9 (6.3)	96.5	285 (545)	407 (765)
3/4/83	17:32-20:21	95	E	11244	2372[j]	279	98.4 (217)	2.7 (5.9)	97.3	277 (530)	435 (815)
3/4/83	21:27-22:09	43	E	11101	--	250	97.1 (214)	2.4 (5.3)	97.5	307 (585)	424 (795)

[a] ppmv = parts per million by volume as carbon C_1 quantitated against propane. Gas sampling locations are shown in Figure 5-1.
[b] Data collected during these periods represent a SLA residence time of approximately 0.036 sec. All other data represent a residence time of 0.029 sec.
[c] Based on 6 minutes of data analysis.
[d] Based on 63 minutes of data analysis.
[e] Inlet concentration based on 15 minutes monitoring during this period.
[f] Based on 42 minutes of monitoring.
[g] Process down period not included in average.
[h] Based on 9 minutes.
[i] Based on 63 minutes of data.
[j] Based on 39 minutes of data.
[k] Destruction Efficiency $= \frac{Min - Mout}{Min} \times 100\%$, where

M = THC Mass Rate $= \frac{(V) \text{ moles C}}{10^6 \text{ moles gas}} \times \frac{12 gC}{\text{mole C}} \times \frac{\text{mole gas}}{0.024 \text{ m}^3 \text{ gas}} \times \frac{(Q) \text{ m}^3 \text{ gas}}{\text{sec}}$

V = THC concentration (inlet or outlet), ppmv

Q = gas flowrate (inlet or outlet), Nm^3/sec

APPENDIX C

EQUIVALENT INLET THC CONCENTRATION FOR PLANT C-6

The method used to calculate an "equivalent" inlet THC concentration for Plant C-6 is presented in this section. An estimate of the concentration was required for the comparative analysis presented in Section 6.3. The calculation of inlet THC mass rate for the Plant C-6 incinerator will be discussed first. The equivalent concentration calculation method will follow.

The total inlet THC mass rate of Plant C-6 was determined as the sum of THC mass rates in three gas streams: main inlet, floor sweep, and combustion air. These gas streams and the corresponding sampling locations are shown in Figure C-1. The total inlet THC mass rate was calculated as follows:

$$M_{tot} = \Sigma M_i$$

$$M = \frac{(V)\ \text{moles}}{10^6\ \text{moles gas}} \times \frac{12\text{gC}}{\text{mole C}} \times \frac{\text{moles gas}}{0.024\ \text{m}^3\text{gas}} \times \frac{(Q)\text{m}^3\ \text{gas}}{\text{sec}}$$

where M = THC mass rate (main inlet, floor sweep or combustion air), g_C/sec

Q = gas flowrate (main inlet, floor sweep or combustion air), Nm^3/sec

V = THC concentration (main inlet, floorsweep or combustion air), ppmv

Although the actual inlet THC concentration at the incinerator inlet was not measured, an equivalent concentration can be estimated from the total inlet mass rate:

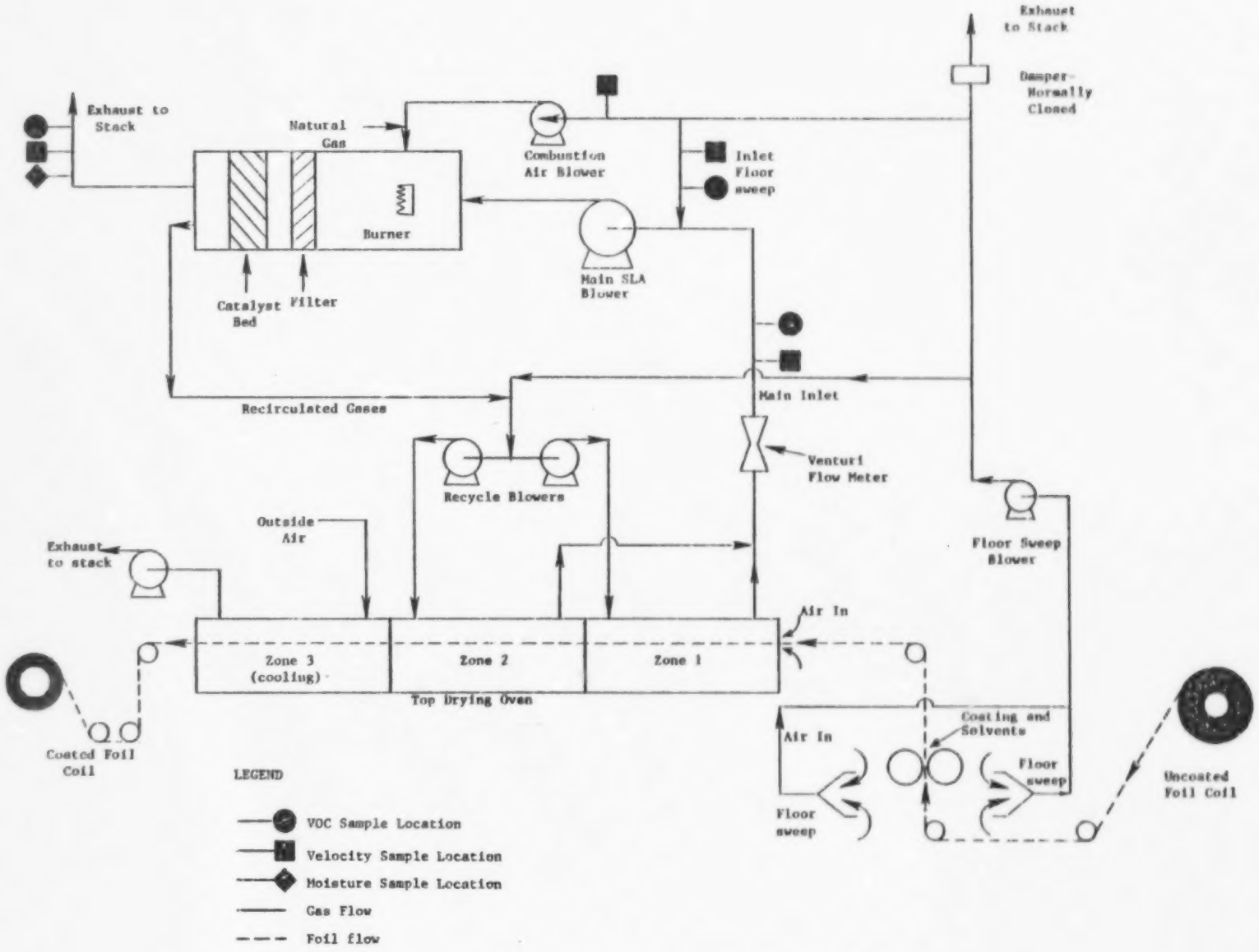

Figure C-1. Process flow diagram showing sample points for Plant C-6.

Figure C-1. Process flow diagram showing sample points for Plant C-6.

$$V_{in}, EQ = M_{tot} \times 10^6 \text{ moles gas} \times \frac{\text{mole C}}{12 \text{ gC}} \times \frac{0.024 \text{ m}^3 \text{ gas}}{\text{moles gas}} \times \frac{1}{(Q_{tot}) \text{ m}^3\text{gas/sec}}$$

where V_{in}, EQ = equivalent inlet THC concentration, ppmv

Q_{tot} = sum of main inlet, floorsweep and combustion air gas flowrates, Nm^3/sec.

The inlet concentrations presented for Plant C-6 in Section 6.3 were calculated using the above equations. The total inlet THC mass flowrates used for the calculations were taken directly from the Plant C-6 test report.